SOIL CONSERVATION

CLAUDE R. WICKARD
Secretary of Agriculture

HUGH H. BENNETT
Chief, Soil Conservation Service

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DISTRICT GIVES BLOW LAND NEW 95-YEAR LEASE ON LIFE

BY A. M. HEDGE [1]

AN HISTORIC step has been taken by directors of the West Ottawa Soil Conservation District in placing 1,436 acres of tax-reverted lands under a long-term, systematic plan of conservation and management. Land was leased by the district after it had been transferred to the county under Michigan's tax reversion act.

Like many other States, Michigan has been plagued for years with the perennial problem of what to do with tax-delinquent lands. Efforts to sell these lands for back taxes and penalties were fruitless in many instances because no bidders wanted the lands. Where such sales were made, to bidders who were interested, the new owners were no more able to make a living and pay taxes than the folks who had just lost the farms. Thus it turned out that the counties were faced with periodic tax sales on the same farms every few years, and the land meantime was becoming ever more useless because of mismanagement and abuse.

In 1937 the tax laws of the State were amended to provide that land that is tax delinquent for 3 years will automatically revert to the State. The owner is given an additional year in which to redeem his title by paying the taxes and penalties. Land that is not redeemed is handled in one of two ways, depending on its location in the State. North of a line approximating Town Line 40, and roughly separating the cutover area from the agricultural and industrial part of the State, all reverted lands are placed under the jurisdiction of the State Department of Conservation. South of this line reverted lands are handled by a State real estate board created by the law. Ottawa County lies south of Town Line 40, and is in the area that comes under the jurisdiction of the real estate board.

[1] Chief, regional division of land management and institutional adjustments, Ohio Valley Region, Soil Conservation Service, Dayton, Ohio.

The State tax law provides that the real-estate board shall advertise and sell lands certified as tax delinquent, to the highest bidder, provided the bid is enough to cover the back taxes and penalties. Lands that cannot be thus disposed of are appraised by the board and may be sold for the amount of these appraisals. If bids are not equal to the appraisal, the board may give title to any political subdivision of the State requesting the lands.

That is how Ottawa County recently came into possession of 1,436 acres. The law specifies that political subdivisions receiving land in this manner must dedicate it to public uses for a period of 10 years. The problem was one, therefore, of securing for this land an assured plan of conservation management over a long period of time and of guaranteeing, insofar as possible, that the management in future years would not permit conditions to recede to the status that caused the parcels to go tax delinquent.

To meet this problem the county supervisors decided to lease the land to the board of directors of the West Ottawa Soil Conservation District for an initial period of 50 years, with automatic renewal privileges for three periods of 15 years each, making a total of 95 years if the lease runs its course. Under the terms of this lease the district pays the county $1 rental.

The district assumes full responsibility for development, improvement, protection and management of the land, collects all revenues and pays all expenses, causes a long-time plan of development and management to be prepared which must be approved by the county supervisors and the director of the State Department of Conservation before it is initiated. The county supervisors agree to cooperate in effectuating

this plan by appropriating county funds to the extent they are available, supplying relief labor to be used on the land under the direction of the district, and lending to the district county-owned equipment when it is available.

The district is to report to the county annually on the progress of the plan and to account for all receipts and expenditure of county or district funds. When from these annual reports it becomes apparent that the district is making a profit from operating the lands, the county and the district are to come to a mutually satisfactory agreement as to what part of the profit shall be paid to the county as rental.

The land covered by this lease has little possibility of being profitably farmed. Much of it is blow sand that is not only unproductive but is a serious menace to adjacent agricultural land because it is continually moving with the wind. The first and most important problem, therefore, is to stabilize and fix these shifting sand areas. Technicians of the Soil Conservation Service are now assisting the district in the preparation of plans for the use of beachgrass, brush, and paling windbreaks, to be followed by reforestation. Trees for this purpose will be available partly from the nursery operated by the district, and partly by purchase with county appropriations. The State Forestry Department is also contributing some trees. The CCC camp located at Grand Haven will supply part of the labor needed for this improvement.

Not all of the land is shifting sand. On a suitable site the district plans to establish some transplant beds, thus increasing the capacity of their present nursery. One or two parcels are capable of being farmed if proper conservation practices are followed. On these farms complete conservation plans are being prepared, and they will be leased to farmers who will agree to follow these plans. Portions of still other farms are capable of being operated under careful conservation practices. These fields will be rented to farmers who will agree to follow the plans made by technicians of the Soil Conservation Service.

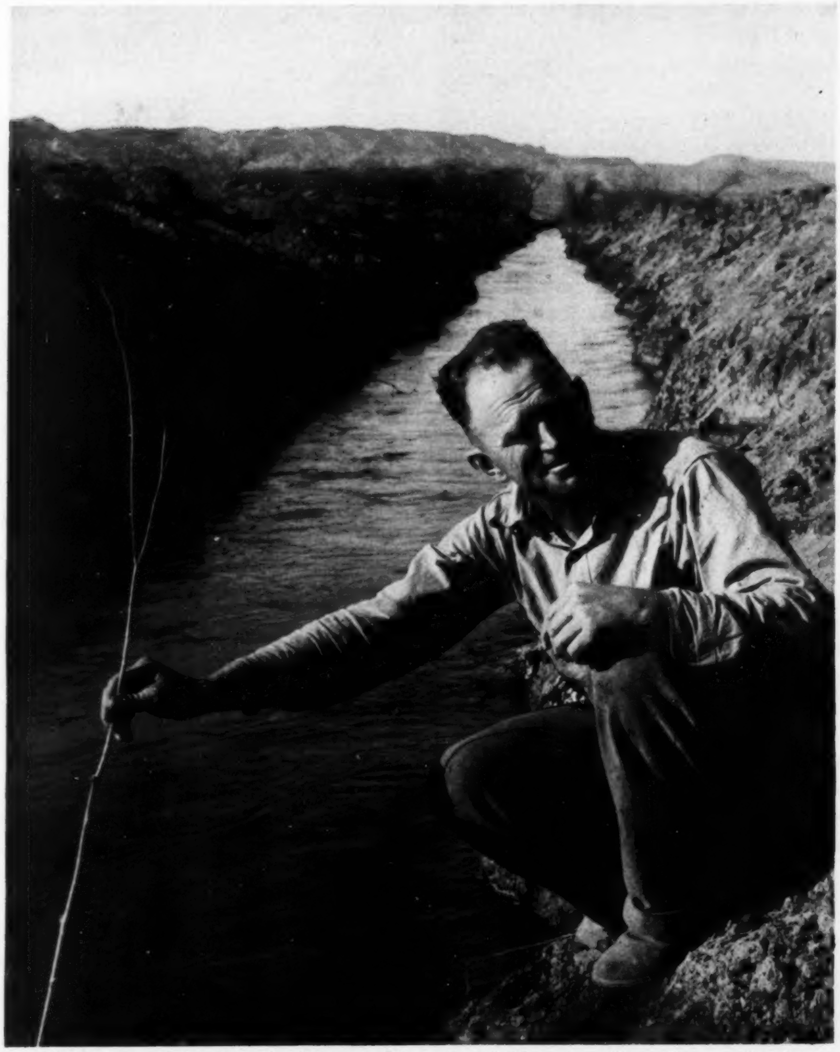
Several sets of buildings are to be removed and salvaged. Old neglected apple orchards are to be removed from 15 acres as a sanitary and disease-control measure. To produce needed revenue at an early date some Christmas trees may be raised and marketed. Improvement cuttings in existing timber stands will be made and the products of this operation will be sold as fuel wood, poles, or pulpwood. Revenue from these sources will be put back into improvement of additional acreage. In plantings made for sand fixation, various materials that will provide game cover and food will be utilized. Since much of this area is near Lake Michigan it is thought that several sites will have definite recreational value, particularly when forest plantings have grown enough to give protection and enchance aesthetic values. These areas will be made available to the public on ground-rental contracts and private individuals may build their own summer cottages.

By this arrangement between the West Ottawa Soil Conservation District and the Ottawa county board of supervisors, a long-term plan of conservation management is provided for once chronically tax-delinquent lands within the district. These lands which under private ownership have failed to contribute their share toward the cost of local government will be improved and developed into a county asset; furthermore, after maturity of a timber crop on them, they may ultimately return to the county much more than they would if they had been left on the tax rolls. In the meantime their menace to surrounding good land will be removed and the county will not be faced with the necessity of finding, every few years, another unwary buyer for a piece of land that cannot produce its assessed taxes.

The Vernal Mesa Soil Conservation District near the Grand Canyon of the Gunnison River in western Colorado is tackling a tough erosion problem caused by slides on a steep slope above the main irrigation canal. Huge drifts of snow, as much as 25 feet deep, occur above the canal. When the snow melts and the water soaks down through the open soil to impervious layers of shale, the whole hillside begins to slide down. First a metal flume replaced the open ditch, built in 1905; later two 30-inch steel pipes were placed underground to carry the water through the slide area. Maintaining the canal at this point has cost as much as $3,000 per year. In this district there is also another serious erosion problem caused by the waste water from potato and alfalfa fields.

Three hundred and sixty pounds of kudzu seed have been planted by farmers in the Piedmont Soil Conservation District in Alabama. These plantings were made with the idea of producing seedlings for use by growers and their neighbors in establishing kudzu meadows, waterways, and in retiring severely eroded lands to this valuable soil conserving plant.

KEY SPOT PROJECT IN NEVADA



C. O. Bastian, chairman of the Lincoln County, Nev., Land Planning Committee, referring to this ditch, says: "The S. C. S. job in Pahranagat Valley has doubled the value of the three farms involved."

NEVADA'S small and scattered fertile valleys are sometimes called "land-use bottlenecks," and they are actually that, because regardless of how productive of grass the surrounding range may be a stockman cannot maintain a herd larger than his supply of supplemental feed—and this feed must be grown in the valleys. Surveys indicate that 50 percent of the livestock for the entire year comes from the valleys, which in area comprise but a very small fraction of the State.

The Soil Conservation Service program in Nevada is helping to keep these key spots, or land-use bottlenecks, in balance with the millions of acres of surrounding grazing lands whose value is dependent to a surprising degree upon the welfare of the valley lands.

Pahranagat Valley in southern Nevada was first settled by the Mormons in 1870. Normally there are about 6,000 cattle and horses in the valley and on the surrounding range; and about 15,000 sheep use the range either as winter grazing or for "trailing" to other

ranges. The ranges are used during the winter and the valleys in the summer—this because the feed on the range dries up in the hot summer months but is at its best during the rainy winters.

On September 30, 1940, the Service entered into an agreement with the Pahranagat Valley Soil Conservation District. The work plan specified that the Service provide a 1-cubic-yard power shovel and that the district furnish fuel, oil, grease, repairs, and an operator. The job involved the excavation of 9,500 feet of drainage ditch and 2,220 feet of irrigation ditch. The purpose of the drainage ditch was to carry excess winter rains from meadow land into Pahranagat Lake and thus make available a large area for production of summer feed. The irrigation ditch was intended to make it possible to irrigate alfalfa fields from the lake in dry summers. The ultimate objective of the project was improvement of supplemental feed production on approximately 1,245 acres of valley lands.

C. O. Bastian, chairman of the Lincoln County Planning Commission, recently remarked as follows to Albert Sanders, acting area conservationist in Caliente: "The Soil Conservation Service has just completed the job in Pahranagat Valley which has doubled the value of the three farms involved. I know this because I used to farm one of the places myself, and if I were to buy it back today I would have to pay twice the price it sold for."—Charles D. Jarrett.

SOUTHERN NEW ENGLAND FERTILIZER CONFERENCE

BY A. T. SEMPLE [1]

I. CONTRIBUTIONS TO GRASSLAND FARMING

IN THE United States there has been an unmistakable trend toward grassland farming since the First World War. Unprofitable crops, erosion difficulties, and the help of the action programs in agriculture have been responsible for a considerable increase in grassland, including both permanent and rotation pastures and meadow. To stimulate more interest in this movement, five regional grassland conferences were held last year under the auspices of the State experiment stations, extension services, and the United States Department of Agriculture. Since then a number of State and other regional meetings have given all or a major part of their programs to grassland problems. The seriousness of our national problem of protecting and rebuilding our soil resources and the severe contraction in our export market for cotton, wheat, and other crops, make it necessary that we convert a much larger acreage of our cropland to grass.

The conference held at Amherst, Mass., on March 10 and 11, to discuss new developments in the use of fertilizers, dealt principally with grassland problems. This was quite natural as about 88 percent of New England farm land is in pasture and meadow crops, and very few farmers have enough land or can afford to undertake production of the concentrated feed their livestock require. The principles of soil management and forage production apply in other parts of the country, however, much the same as they do in New England, and for this reason some of the facts brought out at the conference are given here so that a larger group may benefit from them than was represented at the meeting.

Anyone interested in soil conservation or related problems is inclined to have a lot of confidence in what Professor Prince of the New Hampshire Experiment Station says; as an agronomist he is of the opinon that a good sod is a very good if not the best protection against erosion. He opened his discussion by indicating that true grassland farming involves the use of grass, including legumes for silage, without the production of corn or any similar cultivated crop. Since such grasses and legumes produce only about three-fourths as much dry matter per acre as can be secured from corn, it is obvious that the true grassland farmer must expect to use more fertilizers in order to increase yields sufficiently to care for present numbers of livestock. Professor Prince went on to point out some of the advantages of grass silage, stating that it is slightly better in feeding value than corn silage, pound for pound, and that the labor requirements for producing it are less per ton than for corn silage. With the increasing demand for farm labor to man the defense industries, there is bound to be less labor available for farm work. The lesser cost per ton has been proved by both the New Jersey and the Ohio Experiment Stations.

Changing entirely over to grassland farming involves some changes in the farm organization in respect to seeding practices, use of manure, and the

[1] Head, pasture section, agronomy division, Soil Conservation Service, Washington, D. C.

A good pasture gone wrong. Lack of fertility and organic matter in the surface soil has caused depletion of desirable pasture species and the incursion of brush. New Hampshire Agricultural Experiment Station.

kinds of fetilizers and the methods used in applying them. While corn for silage must be planted in the spring, as early as possible yet late enough to miss the late frosts, grass may be sown almost any time during the latter part of the growing season, after spring growth has been removed as a hay or pasture crop.

In the matter of handling manure, grassland presents quite a different problem from that of cropland. Dairymen have been accustomed to using rather heavy applications of manure on their cropland—30 to 40 loads per acre. Such heavy applications tend to be wasteful because of rapid decomposition and the loss of nutrients not used by the following crop.

Professor Prince pointed out that 10 loads of manure per acre is about the correct amount for top dressing of hay land. Records are in existence in northern New Hampshire of land that has not been broken since the 80's and is still producing 2 to 3 tons of hay per acre. This indicates the possibilities of permanent hay land if it is properly managed. Until very recently when some superphosphate was applied this meadowland had no treatment other than manure. As much as 20 loads should be worked into the land when it is broken to establish or re-establish a stand of grass. Even with such applications of manure, balanced with superphosphate, it may be difficult to maintain hay land on some of the lighter soils for more than 5 or 6 years. Accordingly, as a part of this problem of grassland farming, it is very important that the land-use capabilities of all soils on the farm be carefully considered.

At present, much land is being used for hay and pasture that would be much better off from the standpoint of erosion, flood control, and profit to the farmers, if it were in forest. Obviously, the acreage of better land, such as classes 1, 2, 3, and 4, which a farmer has available, would determine the extent to which he could convert classes 5 and 6 from pasture to tree production. Wherever better land is available, certainly there is nothing to be gained, either by grazing or by growing a hay crop on land with grass so poor that it may pay to cut it but not pay to rake it up.

Professor Prince has under way a very valuable experiment to determine the relative values of (1) applying all of the superphosphate and potash necessary for a 3-year period at one time, and (2) dividing it into three equal portions and applying one-third of the amount each year over the 3-year period. The first 2 years' results indicate a considerable advantage in putting the whole 3-year treatment on at the beginning of the 3-year period.

In the discussion that followed, Professor Brown pointed out Connecticut Experiment Station records showing that land that will produce about 4 tons of dry matter in the form of corn silage will produce only about 3 tons in the form of grass silage with legumes predominating. With the true grasses predominating, the ratio between corn and grass would be considerably wider than 4 to 3.

These data from the Connecticut station answer the objections oftentimes made to a grassland program, that it threatens to increase livestock production to such an extent that it will have a bad effect upon the market. Even in the cases of cotton and wheat, about half of the crop is used for livestock feed in the form of cottonseed meal and hulls, bran, middlings, etc. There is little evidence to indicate that the grass being grown on land taken out of cotton and wheat, is producing as much livestock products as would have been produced by the cotton and wheat by-product feeds.

Changes to grassland will help livestock men by enabling them to produce meat and milk at lower costs per unit, since grass and especially pasturage is a cheaper feed than grain and other concentrates. In addition, the soil is maintained much more effectively where grassland has a big part in the production of livestock products. Some change in the distribution of livestock production is to be expected, and also some change from hogs to cattle and sheep, but the total production certainly is not adversely affected

and the market outlet is materially broadened because more meat and other livestock products are made available on farms that in the past have not had enough of this kind of food for home consumption.

Dr. Midgeley, station agronomist for the University of Vermont, gave a discussion of pasture and hay land management. He reemphasized the futility of attempting to apply fertilizers to lands of low water-holding capacity, such as sand hills, where water is the limiting factor in production. He showed how the taller-growing grasses desirable in hay lands, because of their greater yields, are rapidly killed out when they are grazed, just as they would be by frequent clipping. Of the tall-growing grasses, apparently only orchard grass is able to hold out under close grazing or frequent clipping. He emphasized the fact that adequate fertilization encourages their growth and makes it possible for them to shade out the turf-forming grasses that otherwise might decrease meadow production.

Dr. Midgeley also discussed nurse crops, pointing out that almost invariably the term "nurse crop" is a misnomer, in that it does not in any way help the young seedlings of the legumes and perennial grasses In fact, it is often a detriment to them, since it causes them to make spindling growth so that they are killed if or when the nurse crop is cut off and only the bare stubble of the seedlings is left. About the only redeeming feature of a nurse crop is that it takes the place of weeds that might otherwise compete with the grass seedlings and thus supplies a crop of some value to the farmer's pocketbook. The cutting of the nurse crop is generally the last of it, while most weeds are likely to make some seed and continue as pests or competitors to the forage.

The possibilities of grass silage were discussed by Prof. C. H. Parsons of the Animal Husbandry Department, Massachusetts State College. He listed four advantages of grass silage in the preservation of crops:

(1) There is less loss of nutrients, since the material is put up green, and there is no loss of leaves and no loss by leaching such as occurs when rain or dew falls on grass while it is being made into hay. The moisture content of the green material should be between 60 and 70 percent, while that of material put up for hay should not be more than 20 to 25 percent. Obviously, about three times as much water must be handled in making grass silage as in making hay.

(2) In the making of hay, often there are odds and ends about the field, growth from shaded areas, hay not stacked for one reason or another, which can be put away as grass silage and thus not wasted.

(3) Harvesting part of the grass in the form of grass silage makes it possible to get more of the crop harvested in the desirable stage before over-ripeness. When the crop is cut only in the form of hay, at least a third of the work time cannot be utilized in harvesting hay because of early morning dews, cloudy or rainy weather. Much of this time may be utilized to harvest grass silage, and in this way more of the crop can be harvested during the month of June.

(4) Grass silage may serve as a substitute for green pasturage during dry, hot periods in July and August. Putting up enough grass silage for a month or more of such midsummer feeding is more economical than depending on soiling—that is, cutting green crops daily and hauling them to the cattle.

In considering the labor requirements and the way grass silage fits into the farm organization in comparison with corn silage, Professor Parsons was reminded of the story of the three men who appeared at a railway station and asked how soon the north-bound train would be in. When the agent said in just a few minutes, they decided to cross the street for some refreshments. They returned and asked how soon the train would be in. When they were told it would be in any minute, they again crossed the street for refreshments. When they came out this time the train was just pulling out of the station. All dashed madly to catch it. Two got on and one was left behind, and he stopped and laughed at great length. Finally someone asked him why he was so happy about missing the train. He replied, "Those two fellows came down to see me off!"

Thus it is that what the farmer gains in one way, he may lose in another. While grass crops for silage require less labor than corn for silage, they may conflict with haymaking operations to such an extent that the farmer would be better off if he had some corn land as a source of silage in order to get a better distribution of his labor. Also, having both grass and corn as sources of roughage, he may be in a better position to get through the "bad" seasons when it may be too dry for grass or too wet for corn. Such inconveniences, in case the farmer is depending on grass alone, may be avoided however by carrying over grass silage or both hay and grass silage, from one year to the next so that he has a reserve for a poor season such as 5 or 6 weeks of summer with little or no rain.

An additional advantage of grass silage is its high carotene content, and also the high content of scorbutic acid. The flavor of milk is also improved by the use of grass silage. These are excellent selling points for dairymen who are in a position to market their own

milk and establish a reputation meriting some price premium for milk of high quality.

Professor Donaldson, extension agronomist of Massachusetts, noting that some of us were taking notes, tried to put a stop to it by showing a series of slides to illustrate the forage that may be used to supply an abundance of forage of high quality throughout the growing season. They appeared in approximately the following order, corresponding to the progress of the season:

(1) Rye.
(2) Hay land that has been top dressed.
(3) Permanent pasture that has been fertilized.
(4) Ladino clover for half-day grazing or night pasture, because of its extreme luxuriance of growth and high palatability.
(5) Oats.
(6) Alfalfa following the first cutting for hay.
(7) Ladino clover on wet land for midsummer use.
(8) A mixture of millet and Sudan grass, 15 pounds of each sown about the last of June.
(9) Grass silage for droughty periods.
(10) Rowen, following the first cutting of hay.
(11) Orchard grass.
(12) Early-sown rye.

The points he sought to emphasize in the pictures were as follows:

(1) Farmers do well to seed the kind of mixtures best suited to their types of soil, such as alfalfa mixtures on the well-drained soils, and mixtures including some Ladino for the moisture areas of the farms.

(2) Adequate top dressing of grassland is the most effective means of increasing longevity and productive yields. Farm trials have demonstrated that the tonnage of feed was more than doubled and costs per ton of the increase were less than $5 per ton of dry material.

(3) Grassland crops should be utilized in accordance with the needs of the herd for feed. Grazing requirements should be met first; then hay or silage should be made from the balance.

In the discussion that followed, Brown of Connecticut cited the experiments at Rothamsted in which hay land has been top dressed for 98 years, and still satisfactory yields of hay are being obtained. He also pointed out that the Storrs Station has some evidence to show that the working in of phosphate and lime does not pay. In another experiment there is no significant response from potash on grazed plots, while hay plots over the fence will not produce a stand of clover without the application of potash. This is an example of how potash may be maintained much better on pasture than it is on hay land where the manure is not returned or is largely wasted in the process. He emphasized that with as much as 50 percent of legumes in a hay or pasture mixture, there was little or no advantage in using a fertilizer containing nitrogen except to provide earlier feed, and certainly there was no advantage where the mixture consisted of as much as 75 percent legumes. The value of Ladino clover was emphasized by the statement that including it in a mixture of timothy and red clover increased the yield about one ton per acre over a 3-year period.

II. SOME FACTS ABOUT ORGANIC MATTER

IN ADDITION to his talk on grassland farming at the conference, Professor Prince was loaded with fac ts andfigures on "the importance of organic matter." He showed how organic matter reaches its final stage of decomposition, that is, it is broken down until it becomes simply carbondioxide, water, ammonia, etc. This process may take several years, or it may come about with almost the speed of an explosion as in the case of crotalaria which at Gainesville, Fla., was observed to have disappeared completely within 6 weeks after being plowed under. He emphasized trying to increase the organic-matter content of soils above a certain level as a usually wasteful practice. This does not always hold true, however, as in the case of some soils formerly in forest and now being used for the growing of crops. A notable example occurs on the West Coast where certain soils now used as cropland contain about one-third more organic matter than the forest soils in their virgin condition.

For comparison of organic matter losses he cited the Ohio experiments, in which such losses from a 5-year rotation of corn, 2 years of small grain, and 2 years of clover and timothy, were slightly more than from a 3-year rotation of corn, small grain, and red clover. It appears that the more complete decomposition of the timothy in the grass mixture, resulting from a more limited supply of nitrogen, may be the explanation for greater loss of organic matter in the 5-year rotation. As J. B. Abbott pointed out later, when organic matter decomposes in the absence of sufficient nitrogen the decomposition may go further, with more CO_2 being liberated than if sufficient nitrogen is present to maintain a biological balance in the soil to hold nutrients that otherwise would be lost or made unavailable for plant use. Over a 32-year period in the Ohio experiments, the limed plots held more organic matter in the soil than the unlimed plots.

Professor Prince cited records kept at Blacksburg, Va., for work started in 1917 to show that on pasture

1938 hay crop, Livingston farm, Claremont, N. H. Land manured uniformly in 1936. NPK plots received 100 pounds of nitrate of soda, 400 pounds of 20 percent superphosphate, and 150 pounds of 50 percent muriate of potash. Hay yields over a 3-year period have averaged 4 tons per acre on the heavily fertilized plots, which is 3 times the yield from the check plot.

plots where 200 pounds of superphosphate had been applied annually, the surface 2 inches of soil contained 96 percent more organic matter than the untreated plot, and the next 2- to 6-inch layer contained 23 percent more organic matter. This increased amount of organic matter helps to keep the phosphate available by preventing it from becoming permanently fixed in the soil. It has been proved that where the soil contains adequate amounts of lime and organic matter, there is no serious problem of the phosphate becoming unavailable for use by the plants through permanent fixation in the form of iron and aluminum compounds.

He emphasized strongly that crop rotations alone are not sufficient to maintain the organic-matter content of soils; that lime, crop residues, manure, and fertilizer in varying amounts are also necessary. The larger yields incident to fertilization and the greater amount of crop residues including larger root growth, obviously are important in maintaining a desirable amount of organic matter in the soil. He pointed out the value of livestock in making possible a larger return of organic matter and plant food to the soil than in straight grain or other cash-crop farming.

In considering the value of rotations and legumes as one of the means of maintaining soil productivity, it is very important not to overlook the value of grasses, particularly the perennial grasses, in improving soil structure. This is emphasized in publications by Bradfield, formerly of the Ohio Experiment Station and now head of the Agronomy Department at Cornell, and Stauffer, of the Illinois Experiment Station. Stauffer's work shows that where crop residues and manure were returned to the soil, the organic matter was slightly higher than in permanent bluegrass adjoining the cultivated plots. However, the physical condition of the soil, as shown by the number and size of the soil aggregates and the increased rate of infiltration, proved the value of grass in improving soil structure. The fact that under most conditions organic matter from grasses does not decay as rapidly as that of legumes is also an indication of the importance of including perennial grasses as well as legumes in crop rotations.

Dr. Abbott, a leader in agricultural research in the commercial fertilizer field, presented some very significant data covering a 3-year study at the Purdue Agricultural Experiment Station, to show the effect on crop yields on soils containing an adequate supply of phosphate and potash, of adding nitrogen to cornstalks at the time they are plowed under in the spring. The experiments conducted on Bedford, Parr, Crosby, Brookston, Miami, and Clermont soils, included plots in which the cornstalks were plowed under (1) without any nitrogen, (2) with 20 pounds of nitrogen per acre, (3) with 40 pounds of nitrogen per acre, and (4) with 80 pounds of nitrogen per acre. On Bedford soils, the increases in corn yields for the 3-year period, with 40 pounds of nitrogen per acre, varied from 3 to 17 bushels per acre; on Parr soil, from 9 to 16 bushels per acre; on Crosby soil, 7 to 26 bushels per acre; on Brookston (2 years), from 8 to 17 bushels per acre. Increases for Miami soil of from 5 to 12 bushels per acre, and for Clermont of from 10 to 25 bushels per acre were obtained from applications at the rate of 80 pounds of nitrogen per acre. The results of this investigation have not been published as the Purdue station wishes to get the results for at least 1 more year's work before drawing conclusions.

The available data for the different soil types, including the residual effect on succeeding crops such as soybeans, oats, wheat, and corn, following the season in which the nitrogen was plowed under with the cornstalks, showed an average net return per acre of $4.41 for 20 pounds of nitrogen; $6.40 for 40 pounds of nitrogen; and $8.49 for 80 pounds of nitrogen. The cost of the nitrogen was figured at 10 cents a pound, wheat and soybeans at 75 cents per bushel, corn at 50 cents, and oats at 25 cents per bushel.

Dr. Abbott went on to say that green-manure crops grown primarily for the production of organic matter generally are rather expensive, considering the cost of seed, of planting, and the extent to which they interfere with the planting of other crops. However, in most instances they serve to protect the soil from erosion and to prevent leaching, thereby offsetting some of the objections to their cost as a source of organic matter. In contrast to the cost of green-manure crops, it is quite significant that crop residues,

It often pays to use some of the most productive land on the farm for pasture.

such as corn or cotton stalks and wheat straw, have no sale value and it may be said that they cost nothing to produce. If they can be made to supply organic matter satisfactorily, without interfering with crop production, and at the same time increase returns sufficiently to pay for the nitrogen necessary to facilitate their decomposition, then they constitute a very valuable contribution to the farm economy and soil conservation objectives. In the Indiana experiments, an expenditure of $2 for 20 pounds of nitrogen returned a profit of $6.40, at the prices cited above.

It was pointed out that, as in the case of cornstalks, when shavings such as those used for bedding, or any other highly carbonaceous materials are applied to the soil, they require an adequate supply of nitrogen and other plant nutrients for satisfactory decomposition and to avoid harmful effects on succeeding crops. The importance of having a well-balanced ration for soil micro-organisms, which convert woody material to humus, is clearly illustrated by the fact that hardwood sawdust derived from trees grown on rather fertile land decomposes much more rapidly than softwood sawdust coming from trees that have grown on very poor land.

In truck farming, where raw manure is rarely applied to the soil and composting is almost a universal treatment, the addition of some nitrogen as well as superphosphate to the compost pile appears to be a very desirable practice. The relatively small supply of manure now available for truck farming could be made to go much farther if the composting was done in the soil where it is to be used, provided adequate quantities of nitrogen were added to facilitate its decomposition and to prevent its interfering with the growth of the crop planted after its application. The danger of losing nitrogen in the decomposition of manure can be avoided to a large extent by adding superphosphate, which tends to prevent losses by leaching or by escape in the form of ammonia and free nitrogen.

This discussion of the decomposition of carbonaceous plant material in the soil and the improvement of the process as a result of adding nitrogen is highly significant in connection with soil conservation. The use of nitrogen makes it possible to overcome the objectionable features of plowing under straw and cornstalks that might otherwise be burned, and in using such crop residues at or near the surface of the soil as a mulch to reduce run-off and erosion losses from both wind and water.

PASTURE MANAGEMENT

Improved pasture-management practices are reflected in conservation farm plans developed by the Soil Conservation Service. These include division of pastures to permit rotation grazing, fertilizing as required by specific soil types, stocking to capacity, deferred pasture use in the spring, clipping and mowing, spreading of droppings, and winter protection.

In the Pacific Northwest, development of upland areas for production of grass seed, and dryland pasture for use by young stock and meat animals provides for a better balanced use of rotation pastures by dairy stock in full production.

MATANUSKA FROM LAZY MOUNTAIN

BY W. A. ROCKIE [1]

IF ONE could take all the cleared land in the entire Territory of Alaska, draw it together into one solid block and have it transplanted, it would not cover more than one-eighth of the District of Columbia. Most of this cleared land is spattered over the upper portion of the Matanuska Valley, and nearly all of it is within 10 miles of Palmer. Thus Palmer is the present farming center of Alaska.

The Matanuska Valley still consists almost entirely of raw land. The Colony settlement, operating since 1935, and the homesteads taken prior to that time, if lumped together, would be only a "drop in the bucket" of the Valley.

Recently I climbed to the summit of Lazy Mountain, some 4,000 feet high. From this vantage point I could see the entire lower Matanuska Valley. Lazy Mountain lies about 8 miles east-northeast from the Palmer community center; yet, on its summit, one almost feels as though he could throw a rock southwestward into town, southeastward to the Knik Glacier, northeastward into the Matanuska coal mines or northwestward to the Willow Creek gold mines in the Talkeetna Mountains. Down the valley to the westward lie the lower Susitna Valley and Cook's Inlet, and beyond these one sees the western extension of the Alaska Range, about 75 miles distant.

Much of this landscape is hidden in clouds during the rainy late summer, but occasionally we have a clear day. The typical summer day here has frequent light showers with general cloudiness and hurried passing moments of sunshine.

On a clear day, from Lazy Mountain, one can see practically every farmstead and field. With the aid of binoculars he can watch the people of town as they walk from place to place, and to the east, in an intermountain valley, the community's band of sheep are pasturing.

On this particular day, a strong breeze from the southeast came down the Knik River Valley, bringing with it grayish-brown clouds of dust that swept for many miles westward and northwestward over this new agricultural center. These dust clouds are seen when strong gusts of wind strike the silt and sand bars in the mile-wide braided channel of the Knik River, lift the finer particles high into the air and spread the dust over the entire valley. The coarser particles are deposited along the timbered edge of the valley as a fringe of sand dunes. Between July 14 and August 7 of 1940 there were 9 days of "Knik dusters," or approximately 1 day in 3. A noticeable deposit of dust settled on the house furnishings in Palmer.

Wind borne sand has blown away the softer portion of this dead tree trunk, Matanuska Valley.

I have met many residents of the valley farms and have noticed that "hot days" are especially unwelcome to these folks. One particular group of people who had come in 1935 from the Lake States, where summer temperatures frequently approach and sometimes reach 100° F., remarked on the heat in the Matanuska Valley. At the time, the thermometer probably registered 75° or 76° F. In 4 years, they have formed a new standard for hot days—this particular day would have been very cool in the Lake States. To me, the temperature was delightful, while to them it was unpleasantly hot.

We are here to make a land-use survey of the valley. A detailed survey on the developed portions of the Matanuska Valley involves much the same procedure as does a similar survey in the United States. Already we have covered most of the developed lands so that, in general, only raw lands remain in the area to be surveyed. Virgin birch-spruce forests extend for many miles, without roads, without settlement, and with but few penetrating trails.

A reconnaissance survey does not require exact

[1] In Charge, Alaska Project, Pacific Northwest Region, Soil Conservation Service, Spokane, Wash.

A typical Matanuska Valley farm home.

locations, but in a detailed land survey the surveyor must know his exact location at all times. Keeping the location accurate is a job requiring much effort, and experience aids greatly. The surveyor must do triangulation, run his land lines and measure his distances in a jungle through which he can see but a few feet and must slowly fight his way while running and measuring lines. Incidentally, he must locate the General Land Office survey corners established 25 years ago and all too frequently tucked away under a bed of "devil's clubs." Every minute of the time he is the center of a swarming mass of mosquitoes, gnats, flies, deer flies, and "no-see-ums." If he wears a mosquito net to protect his head and neck, he shuts off the cooling breeze, while if he does not use the net, the little "varmints" are continually getting into his eyes, nose, ears and mouth, to say nothing of their very efficient biting and stinging mechanisms.

These potential agricultural lands are a "Duke's mixture" of stream bottoms and terraces from both wind-blown and alluvial material, glacial moraine and outwash, lacustrine sediments, mud and gravel river flats, tidal flats and some rather limited areas of outcropping bedrock and of actively blowing sand.

Covering these lands are birch, spruce, and cottonwood forests, several kinds of grassland cover, sedge, and tule marshes. Over much of the land is a tangle of brush cover, commonly including one or more of these shrubs: highbush cranberry, red and black currants, alder, willow, rose, devil's club, silverberry, red raspberry, elderberry, and blueberry. Between and beneath these large plants grow herbaceous plants, large and small, and many smaller shrubs. Each of the many kinds of plants contributes its bit toward mantling this land with protective cover.

Rain falls frequently, so that the luxuriant grass and brush are almost always wet. Every movement in the brush provides an additional cold shower. There is only one protection—"tin" pants and coat, with rubber shoes. "Tin" clothes are made of the heaviest canvas, two thicknesses, with a weave so tight that neither water nor air passes through it. Since the grass and brush is always 2 feet and frequently 6 to 10 feet in height, its wetness is a matter of no small importance.

A good illustration of the weather difficulties of field work has been provided us by a group of movie photographers from "outside" who came nearly 3 weeks ago to take pictures requiring 3 or 4 days. They are still awaiting the 3 or 4 days. They have gone into the field, day after day, at 4:30 a. m., 5 a. m., 6 a. m., 7 a. m., 8 a. m. and later (for usually there is some sunshine in the early morning hours) only to be driven in by lowering clouds or rain about the time their stage is all set and ready to take. These folks are not in jovial mood at this writing.

Severe winds are already causing noticeable land damage in the Matanuska Valley. This grazing area has lost all its topsoil except where still held by the residual tufts of grass.

So much for some of the unpleasant aspects of the task we have undertaken. It also has some intriguing and inviting aspects.

The problem of proper land use here is one of which a few local people have some information and many ideas, but about which most of us know practically nothing. It is most interesting, therefore, to have a part in a study of these lands and their present and potential use. Our studies may aid materially in molding and guiding the future use of the lands of this valley.

The land forms and the soils are so young geologically and climatically that agricultural development should not be patterned after land development in the United States. There are no such soils in the States and it is therefore impossible to foretell what will happen to these Alaskan lands under agricultural use.

Since the soils of the valley are so immature, special problems as to the manner of their use are certain to arise—in fact, they already have been encountered. The soil blows readily and severe "blow" damage has occurred. There is practically no soil cohesion, and bare soil offers but little resistance to destruction by either wind or water. The prevalently strong winds indicate that protection from soil blowing must be carefully and continuously guarded. On the other hand, the usually gentle type of rainfall together with the low annual amount, and a generally gently sloping topography, would tend to indicate that soil washing will not be a dominant problem in the area. However, in certain portions of the area where slope lands predominate, soil washing will unquestionably assume a greater importance than for most of the area with its relatively flat topography.

Agriculture has been practiced in the valley for at least 25 years. Some of the early homesteaders have been successful; others on similar homesteads have not. Some of the recent colonists are successfully farming their tracts, while others are not. The same was true of each of the present high-grade farming sections of the United States. Probably it has been true during the development stages of every region, even in the most favored land areas. No doubt pioneering sometimes failed on good lands largely because little or no information was avialable during the pioneer period as to the capabilities and limitations of the soils.

Alaskan agriculture must be patterned after and predicated upon experience in Alaska in the matter of land-use capabilities. Bringing United States farming methods to Alaska has been one contributing factor to those land-use mistakes that have already been made.

Since thus far so little of the land in Alaska has been cleared and used, it is possible that the wrong methods of land development and use can be recognized and discarded. At the same time, the right ways can be recognized and retained.

DEFENSE—FROM RIDGE TO RIVER

BY L. R. COMBS [1]

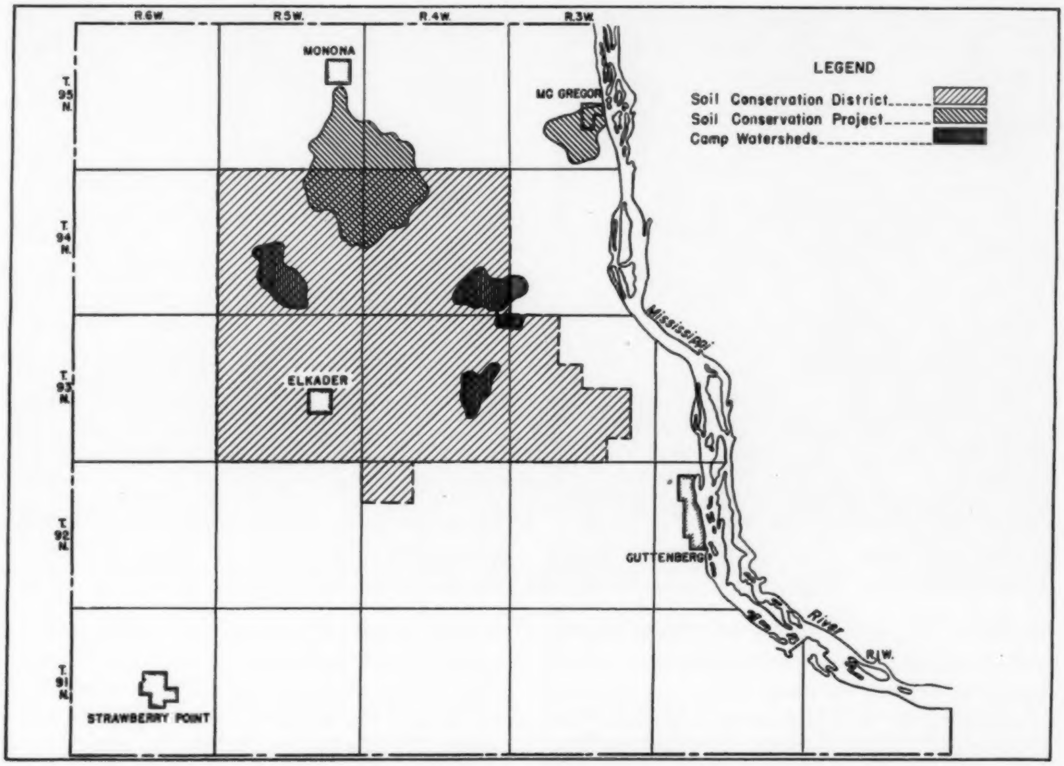
FOR half a century McGregor, Iowa, watched heavy rains turn its streets into raging rivers. Flood waters in the main street sometimes reached a height of 6 feet, swept cars into the Mississippi, flooded stores and residences, and washed houses from their foundations. Usually the streets and sewers were filled with silt and rocks by even the minor floods.

Today this Iowa town can tell a different story, because in recent years the farmers and townspeople, cooperating with the Soil Conservation Service and the Iowa State College, have built a permanent defense against soil erosion and floods. With conservation farming and detention dams, they now control run-off water all the way from the ridges above the town to the great river rolling along at its feet. A 5½-inch rain, one of the heaviest ever recorded, fell on July 26, 1940, and it did not flood the main street sufficiently to float a toy boat.

The McGregor-Farmersburg project area of the Soil Conservation Service includes the McGregor watershed of 2,250 acres and the Farmersburg watershed of 11,500 acres lying farther back from the Mississippi. This is the story of the McGregor watershed, the fan-shaped drainage area characterized by long, narrow, hogback ridges that break into steep rocky slopes and then flatten out into narrow drainageways or hollows. The town of McGregor, situated in the narrow outlet, long had suffered from flash run-off from this area.

According to records unearthed by Emerson Wolfe, formerly project engineer and now project conservationist, and other members of the local Soil Conservation Service staff, the village spent $72,000 for cleaning streets and repairing sewers during the 29-year period ending in 1937. Private losses during this period are

[1] Chief, regional information division, Upper Mississippi Region, Soil Conservation Service, Milwaukee, Wis.



conservatively estimated by some of the older citizens to be in excess of $200,000. For a village of 1,300 persons that is a considerable loss.

The first recorded flood damage was in 1866, about the time the town started construction of a storm sewer system. Other damaging floods were experienced in 1890, 1896, 1902, 1908, 1916, 1924, 1932, and 1934. One of the worst disasters was on June 20, 1908, when 3½ inches of rain fell in 45 minutes. Floods of less serious proportions have occurred within recent decades on the average of once every 2 years.

Damage to the village was not the only serious consequence of intensive rainfall over this area: Each storm washed tons of topsoil from the fields, cut large gullies in natural drainageways, damaged roads, and deposited silt and rock in roadside ditches and streams tributary to the Mississippi River. During 75 years of cultivation, the farm land of the McGregor watershed has lost approximately 60 percent of its topsoil. Some fields are ruined for agricultural production.

The McGregor-Farmersburg soil conservation demonstration project was established in the fall of 1935, and later the businessmen of the town of McGregor asked the project to assist in solving the local flood problem. A committee of businessmen and farmers met with Service technicians and developed a 3-point program calling for the active cooperation of all interested persons and agencies. Briefly stated, the three points are as follows:

1. An extensive soil and moisture conservation program on agricultural land within the drainage area.
2. Construction of detention reservoirs to retard temporarily the excessive run-off from three of the larger hollows, using CCC-camp labor and materials furnished by McGregor.
3. Improvement of storm sewers by McGregor according to recommendations of Soil Conservation Service engineers, to assure proper handling of water discharged by the detention dams.

Thirty-two of the forty landowners in the McGregor watershed developed farm plans with the Soil Conservation Service. As a result, the cultivated land in the watershed has been reduced from 34 percent to 25 percent of the total and is largely protected by improved crop rotations, strip cropping, terracing, and vegetated waterways. Acreages of permanent meadow and protected woodland have been increased.

Mrs. Carrie Schriver, McGregor, shows her neighbor the damage done by flood waters in 1938 when the present land use and flood control system was just being started. The storm sewer was unable to handle the surplus water. Stores were flooded by 2 to 3 feet of water at that time.

McGregor has purchased 54 acres of timberland in order to protect it against grazing, and plans to buy more woodland as it becomes available.

Detention dams were constructed in Walton, West McGregor, and Siegele Hollows. These hollows have drainage areas of 385 acres, 415 acres, and 100 acres, respectively. Each earth dam has two reinforced concrete spillways. One spillway is a small conduit designed to permit a flow of water approximately equivalent to one-half inch of run-off per hour. The inlet of this tube is in the bottom of the reservoir and prevents the impounding of water except when the rate of run-off from the watershed exceeds the spillway's discharge capacity. The amount of water released through this outlet can be handled easily by the McGregor sewer system.

Large emergency spillways of the drop inlet type were built to guarantee safe operation of each dam under extreme flood conditions; they will be in use only during rains of rare intensity. These spillways were designed to discharge approximately 50 percent more than the estimated maximum run-off, or about 6 cubic feet per second per acre of drainage area.

All dams were built with 30-foot tops and 3 to 1 slopes on both upstream and downstream sides. These slopes already are covered with a good sod. Trash screens were installed to protect the spillways.

The reservoirs were designed to accommodate more than the accumulated run-off from a rain of 50-year frequency. In planning the construction, due consideration was given to the effect of vegetative cover and erosion control measures on rate and amount of run-off. Run-off data obtained at the Soil Conservation Experiment Station at La Crosse, Wis., were used in estimating the run-off to be expected from areas devoted to different crops.

Construction work was started in the late fall of 1937 and continued, as weather permitted, until completion in August 1939. Labor was supplied principally by the CCC camp at McGregor. WPA and local skilled workmen were employed to operate certain equipment. During the 1938 season, a shovel and dump trucks were used for constructing the rolled earth fills of the dams, but tractor-drawn wheel scrapers used in 1939 proved more successful.

The Iowa Highway Department cooperated by relocating a half-mile of highway to permit the building of the Walton Hollow dam. The board of supervisors of Clayton County made possible the relocation of a section of county road over the West McGregor dam. The Iowa State Conservation Commission already has purchased about 132 acres of land adjacent to the town for timber and park areas.

In accord with its agreement, McGregor has improved the efficiency of the storm sewers by increasing the cross-section at certain points and changing some of the right angle turns to curves. Work of improving the sewer system will continue as village finances permit.

This combined program of improved land use, soil

An air view of the Walton Hollow detention dam, looking down the drainage area. The road across the top of the dam leads to farm houses in Walton Hollow.

and moisture conservation, and flood control proved its worth on July 26 by holding the 5½-inch rain. During a 12-hour period, the maximum rainfall recorded was 1 inch in 30 minutes, 1.7 inches in 60 minutes, and 5.1 inches in 12 hours. Although the last-mentioned intensity is greater than normally occurs in a 50-year period, the reservoirs were filled to only one-twentieth of their capacity and the storm sewers were no more than three-fourths full at any time during the 12-hour period.

In a small waterhsed it is the high intensity for a short period of time that usually causes the most damage. The 30- and 60-minute intensities were only about 2- and 4-year frequencies respectively, so that the effectiveness of the program under high intensity for short periods is still to be tested. There is little doubt, however, that the run-off will be spread out and retarded even though it may cause the storm sewers to overflow slightly. As additional improvements are made and the storm sewers are enlarged, the danger of flood damage under extreme conditions will be still further diminished.

After the heavy rain of last July 26, it was observed that there was less damage on farm land under the

Typical of ridges around McGregor is this terraced field on the A. L. Henry farm.

conservation program than on nearby fields not so protected. Likewise, the smallness of the silt deposits in the detention reservoirs and storm sewers was evidence of the value of the land-use program and soil conservation practices to the watershed as a whole. There was no flood in the town of McGregor.

But in Marquette, just 2 miles up the river, old residents declared that in their town the water in Bloody Run Creek was as high as ever before, or higher. Officials of Clayton County, in which McGregor is located, estimated road damage at $50,000, while damage to railroad lines was estimated at about $10,000. Five highway bridges were undermined and numerous small culverts were washed out.

Residents of McGregor went about their business as usual the day after the rain storm. How different this experience from that of the past—no salvaging of damaged goods, repairing of property damage, shoveling of mud out of streets, storm sewers, and houses.

The reduction of flood damage and protection of soil in the little McGregor watershed are but part of the results. The McGregor-Farmersburg watershed, the demonstration work established by the McGregor CCC camp, the work of an assistant extension soil conservationist stationed in a four-county soil association, the interest and activity of many local people, have effected a wide spread of conservation practices.

Most recent development was the organization in the summer of 1940 of the Clayton County Soil Conservation District, including five townships in the central part of the county. Ninety-three percent of the referendum vote was favorable. The McGregor watershed was not needed in the district because it lies in the bluff area along the Mississippi which is not primarily agricultural land. Interest was stronger in the more intensively cultivated areas back from the river. The district does include part of the Farmersburg watershed and some of the small watersheds developed in cooperation with the CCC camp. The keen interest in and around the McGregor watershed does indicate that its farmers will petition to be included in the district at a later date.

Summarizing this demonstration work: Residents of McGregor now sleep and work in peace, topsoil is tied down, run-off water is retarded, conservation farming is becoming more common, and a district is well under way in Clayton County.

THE TRANSPORTATION OF SEDIMENT BY FLOWING WATER AND ITS IMPORTANCE IN SOIL CONSERVATION

BY J. W. JOHNSON [1]

General view of Enoree River laboratory near Greenville, S. C.

THE erosive and transporting action of flowing water is undoubtedly the most important factor in soil erosion in most sections of the country. Essential, therefore, to soil conservation work is an adequate knowledge of the principles of transportation and deposition of erosional debris.

[1] Hydraulic engineer, sedimentation division, Soil Conservation Service, Washington, D. C.

From the standpoint of hydraulics, a drainage basin may be considered to contain two distinct erosion zones, each governed by a special set of principles and factors. These are (1) the zone of concentrated flow consisting of actual drainage channels, such as gullies, roadside ditches, streams, and flood plains, in which stream erosion is the major factor, and (2) the zone of more or less unconcentrated flow, constituting the remainder of the drainage basin, in which rain wash and sheet erosion are the major factors. To analyze the problem existing in the first zone, practical consideration must be given to the basic principles of erosion entrainment, and transportation of debris in definite channels. The problem of the second zone is one of evaluating the relationship of overland flow to soil characteristics, climatic conditions, slopes, and vegetal cover.

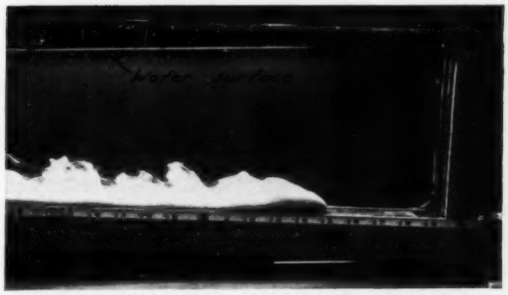
During the past decade numerous studies of the relation of erosion to the various factors of overland flow have been made on small plots. Recently somewhat similar investigations have been initiated on small

watersheds at a number of localities by the Soil Conservation Service. These very interesting and intensive investigations fall within the second zone and will not be considered in this discussion which is intended to treat only of the problems within the first zone, namely, the movement of sediment in defined channels.

In studying the transportation of sediment, separate consideration must be given to the two types of material being transported, the distinction between the two being based on the difference in the laws which govern their movement.[2] With the exception of dissolved matter, the total solids load passing a particular cross section in a stream may be classified either as bed-materials load or as wash load with a definite grain size representing the division between the two classes. The bed-materials load, or "bed load" for brevity, is that part of the total solids load which moves at a rate related to the stream discharge and is composed of the relatively coarse material (coarser than the division grain size). This material moves by rolling or sliding along the bed or by long jumps between points of contact with the bed while in temporary suspension. The wash load, on the other hand, except for a negligible percentage, moves in suspension at a rate which bears no direct relation to discharge and is composed of the relatively fine material (finer than the dividing grain size). The wash load provides much the greater part of the material in a suspended-load sample taken at flood stage and may be looked upon as sediment in relatively permanent suspension.

The grain size which divides the sediment load of a stream into two classes varies in different streams and generally throughout the length of a particular stream, although it has a definite value in a particular reach of a stream. For example, the dividing grain size in the Colorado River near Imperial Dam is 0.01 millimeter (fine silt), whereas in the Enoree River near Greenville, S. C., the size is 0.351 millimeter (medium sand). The dividing grain size can be easily determined from the mechanical analysis curves of samples taken from the bed of a stream immediately after a flood. It is the finest grain size that occurs in the bed in appreciable quantities (more than 3 percent on the Enoree River).

The amount of coarse material in movement varies directly with the stream discharge because enough of this material is available in the bed to load the flow to "saturation." On the other hand, the fine material bears no relation to the stream discharge because there is an insufficient amount of material to saturate the flow.



A stream of heavier silt-charged water flowing beneath lighter water in a model reservoir. S. C. S. cooperative laboratory at the California Institute of Technology, Pasadena.

The available bed load (coarse material) in a stream system ordinarily changes slowly in composition during a long period of years, if at all, and the quantity of the bed load moved is mainly a response to discharge, whereas the wash load (fine material) may vary greatly from year to year and from season to season because of the changing conditions of supply which are independent of conditions of flow. The most important variables of these complexly interrelated conditions of supply are vegetal cover, tillage methods, stage of soil erosion, and climate.

In many small flashy streams almost all of the annual load of wash material is carried during a few days out of the year, and the content of wash material may vary many hundred percent within the period of an hour during the rising and falling stage of the stream. To date no method of wide applicability has been developed for estimating or computing with even approximate reliability the suspended load carried by any small stream; however, investigations of this important problem are now being made by the Sedimentation Division of the Soil Conservation Service.

The wash load is transported at practically the same velocity as the water and usually reaches a downstream point of deposition, such as an area of greatly reduced velocity on the flood plain, or in a reservoir, during the same flood in which the material was dislodged from its source on the drainage basin. The bed load, on the other hand, is transported at relatively low velocities, and moves comparatively short distances downstream in any single flood.

Observations made at the sediment-load laboratory near Greenville, S. C.,[3] have revealed important information on the relative magnitudes of the two types of sediment load in a representative Piedmont stream. During the year 1939, 17,760 tons of sediment were transported in the Enoree River past the measuring

[2] H. A. Einstein, A. G. Anderson, and J. W. Johnson: A Distinction Between Bed Load and Suspended Load in Natural Streams. Transactions American Geophysical Union, Annual Meeting 21 (pt. 2): 628–633, illus., 1940.

[3] G. C. Dobson and J. W. Johnson: Studying Sediment Loads in Natural Streams. Civil Engineering vol. 10, No. 2, pp. 93–96, 1940.

station shown in the accompanying photograph. Of this amount 97 percent was wash load and the remaining 3 percent bed load. Although this ratio between the annual amounts of the two classes of sediment load is not expected to be the same for all streams, or even constant for the Enoree River, it probably represents fairly well the general order of magnitude for streams of the humid sections of the country where the supply of wash load available to erosional attack is essentially unlimited.

Sedimentation damage at various points in a drainage basin may be due to different types of sediment, possibly coming from different sources. For instance, flood and drainage damage caused by stream-channel aggradation appears to be primarily a bed-load problem involving the deposition of relatively coarse material. On the other hand, much of the material deposited in irrigation canals, normally constructed on lesser gradients than the streams which supply them, is very fine. Both fine and coarse material contribute to the deposits in reservoirs, but the finer grade of sediment (wash load) is normally more important than coarser grades because, as indicated above, it is carried in so much greater quantities. Because different types of damages are caused in different proportions by the two classes of sediment it is important that not only the total quantity of the sediment load of streams be determined, but also the relative proportions of fine and coarse material, in order that the principal sources of each type can be determined and effective remedial measures planned.

Although the bed load may constitute only a relatively small percentage of the total sediment load in a stream, practically the entire volume of all the coarse material will deposit as a delta on entering a reservoir. The fine material, on the other hand, may not deposit completely and some of it may pass through the reservoir either by general mixing and subsequent flow over or through the dam, or by passing along the bottom as a density current. In either case, it may be possible, under some conditions, to pass an appreciable amount of the fine material through a reservoir by operation of properly located outlet gates, whereas little or nothing can be done economically to remove the delta deposits of coarse material.

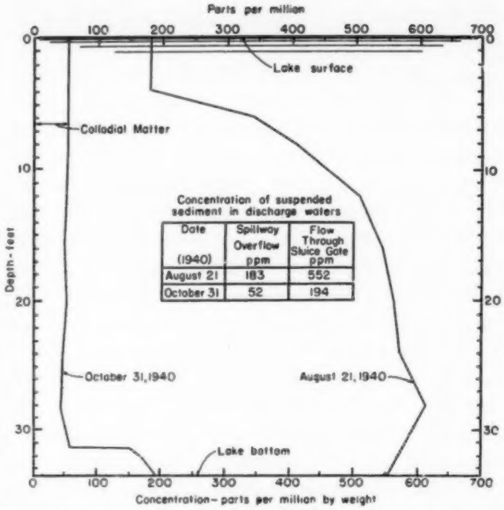
The phenomenon of density currents in a reservoir occurs where the heavier, silt-charged, inflowing waters of a stream flow under the lighter desilted waters already in storage. Because it is not easily discernible, its occurrence had been assumed to be rare, but recent observations indicate the opposite to be true. The high density of the underflow current may be due not only to suspended matter but also to dissolved matter and temperature, or any combination of these factors.

Underflows of sediment-charged water coming from flood flows carrying as much as 15 percent of solid matter, have moved at the rate of over 2 feet per second in Elephant Butte Reservoir. Muddy underflows in this reservoir have repeatedly extended to the dam and have caused muddy discharges through the outlet gates while the surface water of the lake was quite clear. One of the photographs with this article shows a laboratory demonstration of the phenomenon of underflow in a reservoir and indicates the absence of any appreciable mixing of the underflow with the overlying water.

During a flood the lake water in many reservoirs, where conditions favoring underflow are not present, becomes thoroughly mixed with the inflowing sediment-laden stream water and is turbid in appearance throughout the length and depth of the reservoir; later the sediment slowly settles. Eventually all material (except colloids) reaches the bottom and the water becomes relatively clear, if conditions are not altered by subsequent floods.

A typical example of the conditions existing in a small reservoir following a flood is shown on the accompanying chart by the vertical distributions of sediment concentration observed on two different dates in Lake Issaqueena, near Clemson, S. C. This is a recreational lake approximately 2 miles long in which a normal inflow of approximately 20 cubic feet per second maintains the lake level at the spillway crest. In August 1940 exceptionally heavy rains followed in the path of a hurricane which swept the South Atlantic States. A near-record storm occurred on August 13, 14, and 15 during which period a maximum discharge of approximately 1,580 cubic feet per second passed over the spillway of the Lake Issaqueena Dam. The chart shows the vertical distribution of sediment concentration on August 21, 1940, a few days after the flood, and also on October 31, 1940, more than a month later. This latter curve shows that the only water of high sediment concentration remaining in the reservoir is a relatively thin layer approximately 2 feet thick along the bottom.

During the period between observations, sluice gates located near the base of the dam were adjusted to discharge the normal reservoir outflow so that little or no water passed over the spillway. Sediment distributed throughout the body of the reservoir by general mixing during the flood was considerably reduced in quantity during the period of sampling by both settlement of the silt and discharge of water containing high sediment concentrations from the sluice gates.



Date (1940)	Spillway Overflow ppm	Flow Through Sluice Gate ppm
August 21	183	552
October 31	52	194

Vertical distribution of suspended sediment in Lake Issaqueena.

Simultaneously with the observations shown on the chart, samples were taken of the water being discharged through the sluice gates and of water passing over the spillway. The results of these observations, also shown on the chart, demonstrate the desirability of wasting water of high sediment content, as existed in the lower part of the storage space, through the sluice gates, rather than the relatively clear surface water over the spillway. This practice has the twofold advantage of reducing the silting rate in the reservoir by withdrawing sediment before it can deposit, as well as permitting the relatively clear surface waters to remain in storage and thus improve the recreational value of the lake. The findings shown on the chart also indicate that the effect of wasting water through the sluice gates is to create an underflow current within the underlying layer of sediment-laden water. Such a current is, of course, much more feeble than when the inflowing stream passes the length of the reservoir as demonstrated in the model reservoir.

Some writers have implied that erosion-control practices on the drainage area above a reservoir cannot reduce the silting rate in the reservoir by an appreciable amount, because enough sediment already exists in the system of channels to fill the reservoir completely. To refute such a statement it is only necessary to note that the wash load, which constitutes much the largest part of the total sediment load in most streams, does not have its main source in stream channel beds but instead comes from areas where the supply of fine material may be appreciably reduced by erosion-control practices.

In many instances, the silting rates of reservoirs may be reduced by using a carefully planned and controlled method of reservoir operation in conjunction with an adequate program of erosion control on the land of the drainage basin. Erosion-control practices may be evaluated with respect to reservoir-silting control in terms of their ability to reduce effectively the total amount of the load of fine material in the streams feeding the reservoir. A relatively small load of fine material indicates that both upstream and downstream resources are being conserved.

WORKING TOGETHER IN MICHIGAN

A MEETING of State, local, and Federal agencies called in December 1939 by Carl H. Hemstreet, county agent of Grand Traverse County, Mich., has evolved into a regular monthly dinner-discussion group.

Free discussion at monthly round tables, of the policies, services, and aims of each agency and organization, has led to a closer coordination of activities and responsibilities. Participants are representatives of the following named groups: Soil Conservation Service, Agricultural Extension Service, Agricultural Adjustment Administration, Smith Hughes Vocational Education, Federal Farm Loan Association, Northwest Michigan Farm Bureau, Production Credit Association, Grange, Farm Security Administration, Junior Farm Bureau, County Superintendent of Schools, Rural Electrification Administration, Farm Bureau Co-op.

The group has gone one step farther in cooperating toward a more comprehensive and unified farm program. To obtain a better understanding as to how the various organizations fit into the farm picture, an individual farm was selected in which several of the agencies were deeply interested. A soil-survey map, showing soil type, slope, degree of erosion, and a land-use map with economic history and factual data were obtained, and with the aid of this information the entire group worked out a complete farm plan. The plan when finished included a conservation survey map, a new land-use map, special erosion-control practices, a cropping plan, crop and livestock feed requirements, pasture and woodlot improvements, and lime, fertilizer, and seeding requirements.

An important result of this cooperative effort was that each individual became familiar with the work of all agencies.

GOLD AND GREEN ON THE PALOUSE HILLS

BY FRANK B. HARPER [1]

IT WAS about the same time Russell Lord was perfecting the continuity of his ingenious erosion "motion picture" for his TOPSOIL bulletin that the Moscow, Idaho, Soil Conservation Service staff tackled the probably less Martianesque but nonetheless sizeable task of taking some of their big black Palouse hills apart and seeing what made them tick in the erosion solar system.

The undertaking came about when Area Conservationist Leo L. Anderson finally wearied of assuring visitors that "there is more than meets the eye in these hills." He meant of course that the farmers in this, one of the richest wheat-growing areas of the world, not only had real soil erosion to contend with, but also were doing something about it.

The Moscow conservationists already knew from field observations substantiated by cooperators' figures on the South Palouse demonstration project (the first in the Pacific Northwest) that these farmers made as much money—sometimes more—when they had only 80 percent of their land in wheat and fallow or peas and the rest in grass and legume rotations as they formerly made with all of it under the old cash-crop system. Stated differently, 75 percent of the land produced 85 percent of the wheat at only 65 percent of the total family cost. But how had it happened? Many people wanted to know.

To get the answer, Anderson sent agronomists and soils men to more than a hundred of the big dune-like hills. Geologists still are arguing about the formation of these hills; but in the meantime wheat farmers of Idaho, Washington and Oregon have been making tidy livings, and fortunes too, off the land, ever since they first started plowing under the native prairie bunchgrass 60 years ago. In particular, the farmers wanted to know why it is that today, only half a century or so later, they no longer can grow as many bushels of grain on most of this still rich land.

The assignment to cover these rolling hills, with their steep north slopes and sharp tops and ridges, turned out to be anything but just another "snipe hunt" for the shovel- and sickle-equipped technicians. They brought back in their sacks indisputable proof of both the evil and the good that man has been doing to the age-old Palouse. And, today, bold charts for "him who runs to read" adorn the walls of the Moscow offices and form a focus of unfailing interest in fair exhibits, where they shout their own answers to questions about Palouse erosion, its effects on crop yields, and the results of control practices.

It is a long way, up one of these typical Palouse hills with slopes running as high as 60 percent, and down again to the drainageway on the other side, particularly for one who is loaded down with spade and profile cases for taking out 4-foot soil columns every few hundred yards or with harvesting equipment for cutting rod-row samples the length of a mile or 2-mile distance. Actually, because of irregular field and crop boundaries, Agronomist Verle Kaiser ended up with complete yield samples on only 33 of the hundred-odd hills around Moscow in Idaho and Pullman in Washington, and Conservation Surveyor W. W. Hill with profiles—eight to the hill—on fewer than that. But they were enough to tell a real story that may affect the price of a loaf of bread in 1990.

First, for the sake of a realistic picture, take one of the actual hills that was studied—a 320-acre hill that makes an ideal ski run for the young folks of the neighborhood in winter, but from which is harvested in summer perhaps 35, or 50 or more bushels of wheat to the acre. There is no "average" Palouse hill, that is, one that could be used as a pattern to fit exactly many, if any, of the other hills. This particular hill is typical, however, in that it has the characteristic long, moderate south slope, the sharp knife-like top, and the steep north slope.

Although naturally there are no abrupt breaks between the different parts of the slope, the hill was divided into eight comparatively distinct segments, starting at the foot of the south slope where the climbing was easier and the prevailing southwest wind was from behind: The bottom 12 percent was designated as the *lower south* slope; the next 24 percent, the *middle south* slope; and the next 18 percent, the *upper south* slope. The *hilltop* took in 5 percent of the observation course over the hill. Descending the other side, one traveled successively the *upper north* slope accounting for about 1 percent, the *middle north* slope of 9 percent, the *lower north* slope occupying 30 percent, and finally the drainageway amounting to another 1 percent. Thus 56½ percent of the hill had a south exposure, and 43½ percent sloped to the north.

These percentage designations, though quasi-hypothetical, conformed closely to the previously estab-

[1] In charge, current information section, regional division of information, Pacific Northwest Region, Soil Conservation Service, Spokane, Wash.

lished land-use capability classes for such a Palouse silt loam hill. That is, 52 percent falls in class II, 32 percent in class III, and 16 percent in class IV. On this hill, the lower south and north slopes, with their gentler gradients and better topsoil layer, were class II, and may be farmed with only simple conservation measures. These slope segments therefore accounted for 42 percent of this capability class, while the other 10 percent was found along the bottom of the middle south slope. The remainder, or 14 percent, of the middle south slope and the upper south slope of 18 percent were in class III, needing intensive conservation practices. All of the hilltop, the upper north slope by accident of location only, the middle north slope and the drainageway were definitely class IV, to a total of 16 percent of the hill field area, and could not be farmed safely without use of special controls or should not be cultivated at all.

A glance at the display chart for this field which, like the others sampled in the 1935 to 1940 study was farmed under the onetime conventional wheat-fallow system, [2] reveals the following interesting facts about yields per acre and soil profiles:

Hill area	Slope gradient	Yield per acre	Topsoil remaining
	Percent	*Bushels*	*Inches*
Lower south slope	5 to 15	51.4	44
Middle south slope	12 to 20	36.1	18
Upper south slope	18 to 25	19.9	10
Hilltop	0 to 5	14.0	None
Upper north slope	12 to 25	28.0	20
Middle north slope	35 to 50	19.6	24
Lower north slope	5 to 16	45.5	42
Drainageway	0	4.9	....

In other words, the lower slopes of good class II soil, with some 40 inches of topsoil remaining, produced approximately 50 bushels of wheat to the acre, whereas the hilltop from which all the topsoil had been washed away grew only 14 bushels an acre—when 23 bushels of 70-cent wheat is the least for which a Palouse farmer figures he can afford to operate his expensive, heavy combine harvester and thresher—and the white silt-filled drainage yielded but four bushels. A corresponding relationship between the amount of topsoil left on any slope—progressively less the farther up the hill—and the grain yield was disclosed in each of the other five measurements, except on the upper north slope, which had the benefit of extra moisture from snow drifted over the crest from the southwest but without the excessive moisture from snow drifts lying on the middle north slope late in the spring.

Any one of about 30 completely sampled fields told the same story, of hilltop and steep-slope erosion and proportionately lower wheat yields. When Kaiser and Anderson averaged them, this is what they found: [3]

Slope	Present average depth of topsoil	Original average depth of topsoil	Average yield per acre
	Inches	*Inches*	*Bushels*
Lower south	24	30	50
Middle south	10.7	18	35.1
Upper south	4.7	14	22.7
Hilltop	0	9	15.3
Upper north	13.5	18	29.1
Middle north	18.7	40	18.5
Lower north	27.4	36	42.6
Drainageway	* 7.3	....	4.6

* Silt debris.

Here, then, was the factual proof of what previous field observations had shown in a general way: That most hilltops, ridges, and upper south slopes—those slopes that stand out incongruously white or yellow when bare summer-fallow begins to dry out in the spring—have lost from 75 percent to all of their original topsoil, involving approximately 16 percent of this wheat-growing land that is held for anywhere from $60 to $100 an acre and seldom sold. We now had proof also that the major part of the area has lost more than 25 percent of its original topsoil, at the average rate of about 9 tons an acre each year for wheatland. Under the straight cash-crop and fallow system, the once mellow and friable Palouse loams have lost much of their capacity for absorbing moisture, to say nothing of organic matter to the extent of 35 percent and 25 percent of their nitrogen, as shown by earlier experiment station studies. Putting it bluntly, approximately a fifth of this land, originally as good as man ever plowed, has been made submarginal for continued cash-crop farming.

On the Soil Conservation Service staff at Moscow, Idaho, is Agronomist Arden W. Jacklin. He is something of an authority on the growing of grass and legumes in the Palouse—the Service's best solution up to the present for managing that 20 percent, 20 acres out of 100, on which thinning soil and lowered fertility have made grain or seed pea farming a losing business. As yet there has not been time, under the usual 6-year rotation, to study the effect of soil-conserving grass and alfalfa and soil-improving sweetclover on any of the 100 test hills; but Jacklin and Kaiser found other hills on which these forage crops had been grown in erosion-control operation, and another Palouse hill cross-section chart promptly went up on the wall.

This chart showed a 68.7-bushel wheat yield on the lower south slope, 45 bushels on the middle south slope, 2 tons of alfalfa-grass hay from the hilltop and upper

[2] Wheat-pea cropped fields also were sampled.

[3] For complete tabulation, see tables 1 and 2.

TABLE 1.—*Erosion findings on 33 sampled Palouse hills*

Area	Soil type	Average percent slope	Depth of topsoil: Average present	Depth of topsoil: Range present	Depth of topsoil: Average original	Physical condition of the plow layer	Average maximum depth moisture penetration	Erosion: Degree of past erosion	Erosion: Type of current erosion
		Percent	*Inches*	*Inches*	*Inches*				
Lower south slope	Palouse silt loam	11.7	24.0	14 to 36	30.0	Open, mellow, friable; some silt deposition.	72	Slight to moderate.	Infrequent rills. Depth, 6 to 10 inches. Width, 8 to 15 inches.
Middle south slope	do	20.8	10.7	4 to 15	18.0	Slightly puddled and cracked.	60	Moderate	Very frequent rills. Depth, 4 inches. Width, 2 to 4 inches. Infrequent large rills.
Upper south slope	Palouse silty clay loam.	22.0	4.7	0 to 16	14.0	Puddled to subsoil; very hard and cracked; definite plow pan.	30	Moderately severe.	Very frequent fine rills. Depth, 2 to 3 inches. Width, 2 to 3 inches. Infrequent large rills.
Hilltop	Palouse silty clay loam, shallow phase.	0–5.0	None	None	9.0	Puddled, hard and cracked: baked in large blocks; definite plow pan.	15	Severe	Slight loss of soil through wind erosion. Very frequent extremely fine rills, variable in width and depth. Infrequent large rills. Mass movement of supersaturated soil in small rivulets. Moderate loss of soil through wind erosion.
Upper north slope	Palouse silt loam	21.5	13.5	0 to 36	18.0	Mellow and open; some tendency toward plow pan.	32	Moderate	Frequeht fine rills. Depth, 3 inches. Width, 2 to 3 inches. Deposition of wind-blown soil material.
Middle north slope	do	41.7	18.7	6 to 48	40.0	Slightly puddled and cracked on surface; mellow under surface layer.	50	Severe	Very frequent rills. Depth, 2 to 6 inches. Width, 2 to 8 inches. Infrequent mass movement of soil.
Lower north slope	do	11.0	27.4	15 to 36	36.0	Friable and mellow; slightly cracked; some silt deposition.	72	Moderate	Infrequent deep rills. Depth, 6 to 10 inches. Width, 6 to 12 inches.
Drainageway	Johnson silt loam	0–3.0	7.3	0 to 14	......	White; surface baked and cracked; considerable inundation.	Saturated.	Severe	Guily erosion.

TABLE 2.—*Yield findings on 33 sampled Palouse hills*

Area	Yield of Grain: Average per acre	Yield of Grain: Range of yield per acre	Yield of Grain: Ratio of average yield to hilltop yield	Yield of Straw: Number of culms per plant	Yield of Straw: Average height	Yield of Straw: Average per acre	Yield of Straw: Ratio of average yield to hilltop yield
	Bushels	*Bushels*			*Inches*	*Pounds*	
Lower south slope	50.0	29.9 to 83.6	3.20:1	6 to 8	44.1	5,800	3.82:1
Middle south slope	35.1	22.9 to 59.9	2.27:1	4 to 6	35.3	3,700	2.43:1
Upper south slope	22.7	15.8 to 24.6	1.47:1	3 to 5	29.0	2,260	1.49:1
Hilltop	15.3	11.9 to 30.8	1:1	2 to 3	21.0	1,520	1:1
Upper north slope	29.1	14.9 to 53.7	1.89:1	4 to 5	30.7	3,680	2.43:1
Middle north slope	18.5	10.6 to 26.4	1.19:1	2 to 3	36.9	2,100	1.38:1
Lower north slope	42.6	28.1 to 61.6	2.77:1	5 to 7	40.1	5,700	3.75:1
Drainageway	4.6	4.4 to 7.0	.31:1	1 to 3	18.0	700	.46:1

and middle north slopes retired together, with 66.5 bushels of wheat from the lower north slope. This when figured out for the sample field as a whole showed a 6-year yield *under the soil-conserving rotation* of 12,245 bushels of wheat, 65 tons of hay, and 392 animal months of sweetclover pasture, with only 7.76 tons of soil loss to the acre. Contrasted with this was the 6-year total yield expectancy *under a soil-depleting winter wheat and fallow rotation* of only 11,991 bushels of wheat—and that at the cost of 34.62 tons of soil loss to the acre.

The contrasting soil losses under the two farming systems in the Palouse have been measured repeatedly and over wide areas. For example, a survey made after the 1939–40 erosion period, covering 409,425 acres on an undetermined number of farms, showed that land under such a complete erosion-control system lost an average of only 1.3 tons of soil an acre, whereas land under the cash-crop and fallow system lost an average of 18 tons an acre, both in the single season.

From the conservationist's point of view, this soil saving of itself repays the farmer for limiting his so-called cash cropping to his 80 percent of "good" land, seeding his hilltops to grass and alfalfa, either permanently or for at least 4 years out of 6, and keeping his middle slopes in soil-improving sweetclover 2 years out of 6. The preponderance of results during 6 years of demonstration in the South Palouse Project, in coop-

eration with 60 percent of the farmers in the 150-square-mile area, have shown that even the nonresident farmer with a cash- or share-crop tenant on his land can follow a full soil conservation program and make as much or more money than he could by the old cash-crop system, even if he makes no attempt to cash in on his grass and legumes beyond plowing them under for green manure. By adding livestock to his operations, as more and more Palouse farmers are doing each year, he can make money from that other 20 percent of his land that is in soil-conserving crops, although the amount will vary according to his managerial ability.

One representative demonstration farm in the project area showed a year's net increase of $419 after the operator shifted from his soil-depleting program to a soil-conserving livestock farming system—this after allowing for an increase of $565 in the expense of following the new program. The gross income was boosted from $9,754 on the 582-acre farm to $10,933. As worked out for the average 420-acre farm, the net gain in income from utilizing the erosion control crops for supplementary livestock totals $944. The soil-improving sweetclover alone on 360 acres, with wheat figured at 70 cents a bushel and sweetclover pasture at $1 for an animal-month of grazing, raises the net return $555, or from $2,383 to $2,938. On the other 60 acres, valuing the hay at $10 a ton, the soil-conserving alfalfa and grass serve to increase the net return another $389 over the old wheat-fallow rotation income.

A 6-year study covering 4 grain crops on 105 fields showed that winter wheat following sweetclover outyielded that on conventional fallow and pea land by 8.2 bushels an acre, or 27.6 percent. Sweetclover as a green manure crop produces 10 to 12 tons an acre, or provides from 3 to 5 animal-months of grazing to the acre. However, the sweetclover has been found effective in raising succeeding grain yields only on the lower-lying slopes of better soils, and its erosion-control value likewise is fully effective only on these areas. The growing of grass and alfalfa for erosion control is needed on the hilltops, steep north slopes, and the drainages that occupy up to 20 percent of the farming area.

Alfalfa yields 1½ to 3 tons an acre in one cutting. Some farmers sell their hay, and this practice is encouraged from the soil-conservation standpoint because it makes the local hay supply available to livestock operators on surrounding upland ranges and thus helps them to cut down on the grazing use of their land. Other hay is sold to livestock feeders. Grass seed production is still another profitable and increasingly popular outlet for the products of the Palouse farmers' erosion-control cropping programs.

Five years or so ago, the Palouse color scheme in the Moscow-Pullman area was green and black in winter, gold and black in summer—wheat and bare summer-fallow. Today, the style runs to gold and green—wheat still, sweetclover on the slopes and grass and alfalfa on the hilltops. Cattle and sheep now are occupying the barns that stood more or less vacant after tractors replaced the picturesque 20-horse combine harvester teams. Soil conservation districts are pushing ahead with the big Palouse face-lifting process; and all indications are that those who may venture a few years hence to dissect a hundred Palouse hills will need to keep their shovels filed—they will have to dig through tough, soil-protecting grass and legumes along almost any line of sampling in any direction over one of these hills.

"It probably is just as well that the boys gathered their data when they did," Anderson remarked, "because the Palouse is changing fast."

STUDY OF RUN-OFF

INTERESTING studies of the effect of winter ground cover versus bared soil, as related to run-off, infiltration, and soil moisture, have been carried on during the past year at the hillculture experimental plot, comprising 27 acres, near San Juan Capistrano, Calif.

This area is representative of a belt of land bordering the Pacific Ocean, starting at San Luis Obispo and extending southward to San Diego—a distance of over 200 miles—where beans are the usual dry-farmed crop.

The trends as indicated after the first year's study, are that the practice of winter-fallow results in a loss of from one-half to two-thirds of the effective rainfall Run-off on almost virgin land (plowed only once or twice) on a 36-percent slope was only three-fourths as much as occurred on an 18-percent slope that had been in cultivation and subject to erosion for 20 years, and the loss on such land was only two-thirds of what it was on eroded land of one-half as much slope.

The most economical solution to this problem appears to be the management of a winter ground cover in such a manner that it will give protection against erosion, but will leave in storage enough soil moisture for growth of an economic crop in spring and summer.

CLIMATE OF THE SOUTHWEST IN RELATION TO ACCELERATED EROSION

BY C. W. THORNTHWAITE, C. F. S. SHARPE, AND EARL F. DOSCH [1]

FOR two generations, or since about 1885, destructive changes in the land surface in the Southwest have become increasingly apparent. Broad flat-floored valleys have been dissected by deep gullies and the resulting lowering of the water table has diminished the vegetation of the valley bottoms. Trampling and heavy grazing by large herds have greatly reduced the available forage. Ranges that once carried 10,000 head of cattle now can scarcely support one-quarter as many, and valleys that the first white settlers converted into prosperous farms are now deeply cut badlands unsuitable even for grazing.

If, as some workers believe, the dissection of these lands of the Southwest has been brought about by a progressive change to more arid climate it is questionable whether man can effectively stop the accelerated erosion. If, as others are convinced, misuse of the land by overgrazing and imprudent methods of agriculture has been the cause it is quite possible that the land can be improved by improving the use. The evidence underlying these divergent points of view has been examined in considerable detail in a study now in press [2] and the conclusion was reached that the latter view has more to recommend it.

Variability is an outstanding characteristic of climate. Nowhere is the climate of one year just like that of the next. In much of the United States, the variation from year to year, although large, does not endanger the existing land-use economy. But in the Southwest the margin of available moisture is so small that even a slight fluctuation in climate may bring drastic reductions in plant cover. Climatic fluctuations are made up of variations in the several climatic elements of which precipitation and temperature are the most important.

The climatic pattern in the Southwest, and the shifts in climatic zones from year to year, are explained by the atmospheric circulation. The diurnal and annual marches of temperature and precipitation caused by the relation of the earth to the sun are complicated by fluctuations resulting from the invasion and interaction of the various air masses that enter the Southwest. These masses are cool and moist, cool and dry, warm and moist, or warm and dry, depending on the source region from which they come and the route followed (fig. 1). They cause the day-to-day and week-to-week changes in temperature and precipitation (fig. 2). They determine the presence or absence of rain, and the size, shape, internal structure, position, and migration pattern of the individual rainstorm. The almost infinite number of possible sequences of air masses from first one and then another direction, each varying in moisture content and other properties, and an equally large diversity of interactions between air masses, some making for rain and others tending to prevent it altogether for long periods, account for the fluctuations in precipitation and temperature experienced in the Southwest.

Year-to-year variations in precipitation and temperature result in marked shifts in the climatic pattern. An area that in most years is semiarid may be arid

Figure 1. Air masses invading the Southwest may be cool and moist, cool and dry, warm and moist, or warm and dry, depending on the source region from which they come.

[1] Chief, associate soil conservationist, and assistant soil conservationist, respectively, Climatic and Physiographic Division, Office of Research, Soil Conservation Service, Washington, D. C.

[2] C. W. Thornthwaite, C. F. S. Sharpe, and E. F. Dosch: Climate and Accelerated Erosion in the Southwest with Special Reference to the Polacca Wash Drainage Basin, Arizona. U. S. Department of Agriculture Technical Bulletin. (In press.

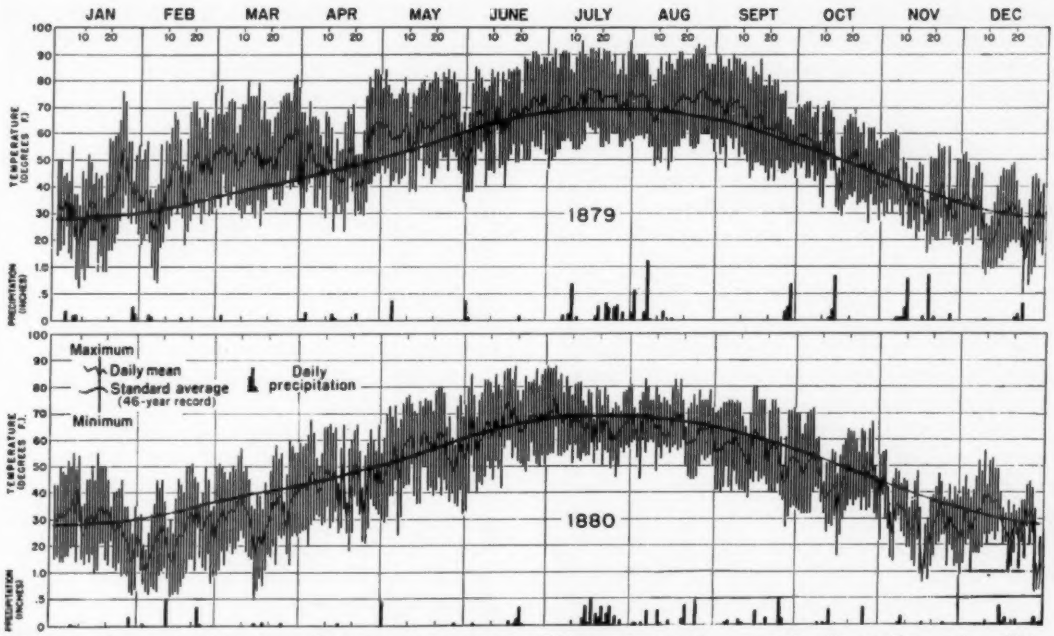


Figure 2. Successive invasions of air masses possessing different properties cause the day-to-day and week-to-week changes in temperature and precipitation shown on these charts for Santa Fe, N. Mex., for 1879 and 1880, respectively, the warmest and the coldest years at that station.

one year and subhumid or even humid the next. Fluctuations from month to month are even more striking. In a given month in one year more than the average annual precipitation may fall. The same month in the next year may be rainless.

Climatic Fluctuations Versus Climatic Changes

In the Southwest as a whole there no doubt have been wide fluctuations in climate during the past several centuries (fig. 3). Various numbers of years in succession have had far above average precipitation while dry years have followed one another as a matter of chance. These fluctuations do not constitute trends in the sense that any appreciable systematic change in climate has occurred.

The climate of the Southwest, as everywhere in the United States, has changed during geologic time; but the changes have been very slow in terms of human reckoning. Even the change since the Ice Age has been gradual, covering at least 25,000 years, and in this region it has not been very great. Climatic changes can take place only very slowly. It appears, therefore, that what often have been called climatic cycles or trends in the Southwest are in reality only short-period climatic fluctuations. The importance of this distinction lies in the fact that climatic trends or cycles correctly identified would have forecasting value, whereas fluctuations have none whatever.

The longest continuous precipitation record in the Southwest, that of Santa Fe, N. Mex., shows that in the period, 1850–1939, there was no progressive trend from which forecasts for future years could be made. Statistical tests for persistence show that the fluctuations in the Santa Fe precipitation record were no different from what would be expected in a random series. However, a record only 90 years long cannot disprove the existence of climatic change.

In the absence of longer rainfall records many indirect lines of evidence have been examined to determine whether there has been any progressive climatic change in the Southwest during the last 2,000 years. In 1913, Henderson and Robbins (*9, p. 68*) summarized the evidence from archaeology, history, botany, and geology available at that time and stated that it was inconclusive; they expressed the "opinion," however, that there had been "progressive desiccation of the region since the beginning of the cliff-dwelling period."

Evidence for or against long-period climatic change must necessarily be indirect, or circumstantial, and therefore difficult to evaluate. However, the only evidence yet presented relating to the last 2,000 years is evidence of climatic fluctuations similar to those we experience today and caused by the same more or less

random interactions of air masses. If there has been any progressive climatic change in either direction it is so small as to be completely overshadowed by these fluctuations.

In recent years the science of dendrochronology, developed in the Southwest by Prof. A. E. Douglass and his students, has accumulated evidence which has been used variously to prove and disprove the existence of climatic change. A statement made only a few months ago by one of the students of tree rings shows that they are indicative of climatic fluctuations rather than climatic changes (*8, pp. 67–68*).

Lake levels in the Great Basin have constantly risen and fallen and have been studied for evidence of climatic fluctuations and progressive changes. According to Antevs (*11, p. 71*) the expansion of the Pleistocene lakes in the Great Basin corresponded to the maximum extension of glaciers in the neighboring mountain ranges and of ice sheets over the northern part of the continent. He places the last major lake expansion at 30,000 to 35,000 years ago. The well-developed shore lines and the lack of deltas indicate that diminished evaporation rather than increased precipitation and run-off was the main factor in the rise of lake levels. That large changes of lake levels in the Great Basin during the last century are associated with upward and downward fluctuations of precipitation is shown by rainfall data supplemented by tree-ring records (*2*).

Archaeological evidence, cited by Powell in 1898, indicates that the Pueblo cultures of the Southwest were developed under conditions approximately as adverse as they are at present (*12, p. lxxii*).

In recent years, Kirk Bryan and his students have presented a tremendous array of physiographic observations as evidence of climatic change. Detailed studies have been made in many valleys of the Southwest that appear to have been filled and evacuated several times in the past. Buried channels upward of one-third mile in length have been traced in the filled valleys of New Mexico (*3, 4*). In the Jadito, Oraibi, and other valleys in Arizona, Hack (*6*) has found remnants of several terraces or benches, each associated with distinctive fill material, which contain buried arroyo channels. These he interprets to be evidence of three stages of filling and three of cutting since the original carving of the valleys. Describing a series of valley fills in the Davis Mountains, Trans-Pecos, Tex., Albritton and Bryan (*1, p. 1472*) say:

> It is a well-established working hypothesis that in an arid climate and in areas of ephemeral and intermittent streams aggradation of valley floors occurs in periods of relative humidity and erosion by channeling occurs in periods of relative aridity.

On a table giving a tentative correlation of the stages of filling and eroding in valleys of western Texas with those of the Jadito Wash, Ariz., described by Hack, each period of aggradation is indicated as "more humid" and each time of erosion, represented in the sedimentary record by disconformities, is shown as "less humid" (*1, p. 1468*). It is worth noting that Huntington (*10, pp. 31–36*) also attributes alternate filling and cutting in the valleys of the Southwest to climatic change, but he believes that aggradation is due to greater aridity and cutting to increased rain fall.

These physiographic observations and their interpretation in terms of climatic change are of much more than academic interest because they have led Bryan to attribute the recent acceleration of erosion in the Southwest to progresssive desiccation. He believes that channel trenching was independent of settlement and its attendant overgrazing although the two happened to be contemporaneous. In a recent address,[3] Bryan concluded that the channeling was imminent at the time when cattle were introduced into the country and the coincidence in time between the introduction of the cattle and the cutting of the channels was the same coincidence as that between the pulling of a trigger and the explosion of the cartridge. This comparison was used again in a paper published only a short time ago (*5*).

Processes of Erosion in the Southwest

Consideration of the processes at work in the valleys of the Southwest will show that neither buried channels nor valley terraces and fills constitute evidence of regional change from erosion by channeling to aggradation of valley floors and back again. Furthermore, the channeling and other features of the valley fill cannot be adequately explained as a result of regional changes in erosion and deposition.

Under natural conditions few of the valleys of the semiarid and arid regions contained perennial streams or even continuous channels down the drainageways. Arroyos were cut locally as a result of heavy showers and the material removed was carried only a short distance down valley and deposited as a fan. The growth of discontinuous arroyos was much like that of the discontinuous gullies formed in many of the valleys in recent years by accelerated erosion. Before the formation of a continuous medial gully down the length of a valley such as the Oraibi, Polacca, or Jadito, in northeastern Arizona, rain falling in one part of a drainage might be felt as run-off for a few miles or tens of miles down valley, but the flow

[3] Great Plains Conference, Flagstaff, Ariz., September 3, 1939.

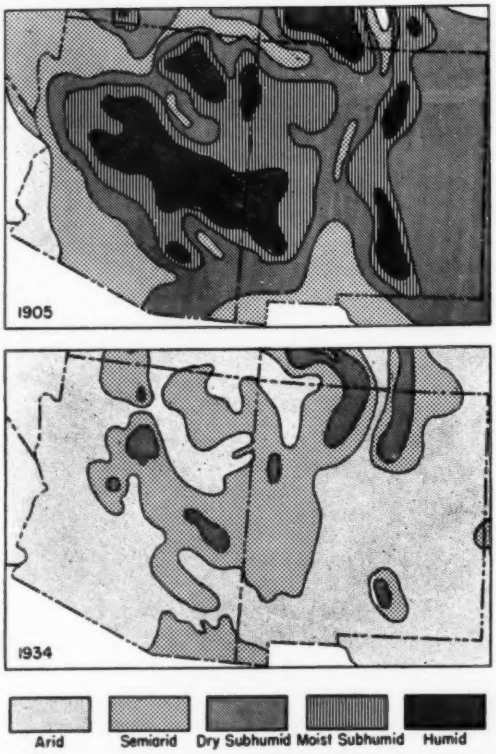


Figure 3. In 1905 an unusually large area of the Southwest had humid climate and almost none was arid. In 1934 none of the region was humid or even moist-subhumid. Arid climate was widespread.

seldom traveled much farther. Reaches of arroyo cutting alternated with reaches of deposition. In times of normal precipitation, arroyos lengthened upstream by headward erosion and at their lower ends became choked and buried by their own debris. Where a series of discontinuous channels was developed down a drainageway the head of each arroyo might cut into the alluvial fan being built by the next arroyo up valley.

Deposition at the lower ends of arroyos by backfilling of the channels (7, *p.* 29) produced waves of sedimentation that migrated up valley. Material removed from the head of the arroyo was transported downstream a few feet or a few miles and deposited. Although the sediment load moved down valley, the individual deposits were enlarged by addition to their up-valley ends, resulting in the upward migration of each locus of sedimentation.

During floods resulting from occasional intense precipitation the flow carried farther than usual. Channels were cleared out and fans were dissected. Dropping of the sediment load formed a down-valley extension of the fan, or, if the lengthened channel intersected another channel down drainage, the load might be carried much farther to form a new fan. Especially in these longer channels, persistent down-valley migration of bends and meanders greatly increased channel width and in time could even cut out an entire valley fill. Excessive run-off from heavy rains, then, by cutting out of older fills caused a down-valley migration of the locus of sedimentation.

Prior to the beginning of accelerated erosion in the Polacca Wash in northern Arizona, five large discontinuous channels were cutting out fill in separate reaches of the valley and depositing it again in fan zones immediately below. With five waves of erosion and five corresponding waves of sedimentation migrating up valley simultaneously, it is obvious that at any one place erosion and aggradation would follow each other consecutively. Each fill would vary greatly in age from one part of the valley to another, depending on the time required for a sediment wave to migrate from end to end of the valley. In regions of semiarid and arid climate neither erosion nor deposition can go on exclusively throughout an entire drainage basin. Rainstorms are local and run-off diminishes rapidly beyond the limits of the storm area. Material picked up by the flowing water will soon be deposited.

The normal processes of erosion and sedimentation, some of which are outlined above, are adequate to produce successive filling and cutting of various parts of valleys without any change of climate. Complex interactions of the up-valley and down-valley waves of sedimentation offer an almost infinite variety of fill sequences. The complicated sedimentary history of many of the valleys in the Southwest is not fully revealed by the few exposures on gully walls, but even so, it is clear that the explanation of successive deposition and removal of fill lies in sedimentary processes and irregular occurrence of heavy storms rather than in any change of climate.

That a land surface which has been irritated by overgrazing and cut by stock and wagon trails will be gullied by a less intense rainstorm than will a surface in its natural condition is well recognized. It is difficult, therefore, to see any reasonable basis for Bryan's claim that overgrazing simply touched off a cycle of accelerated erosion and that gully cutting might have been initiated in the Southwest by 1940 or 1950 even had the country never been settled or used for range.[4] Acceleration of erosion in semiarid areas where the

[4] Great Plains Conference, Flagstaff, Ariz., September 3, 1939.

plant cover has not been depleted by overgrazing or where there has been no other form of irritation of the surface is entirely possible, and it has certainly occurred from time to time in the past. However, under natural conditions the protection against erosion afforded by the vegetation and by the soil mantle itself is sufficient for all except the most intense rainstorms. Most of the storms that contributed to the extensive gullying of the last half-century would have done little or no damage had the surface remained in its natural condition. Rainstorms of sufficient intensity to produce erosion on a surface possessing its natural protective cover are far less likely to occur than the moderately intense rains that brought about the existing gullying.

The accelerated erosion that is damaging the lands in the Southwest appears then to have been brought on by man, and by proper methods man can check the erosion and reclaim the land for his use. Mechanical aids such as diversion dams, distribution ditches, and spreader structures, modernized since the days they were first applied by the Hopis and other agricultural Indians, can be used to keep water out of the gullies and spread it on the valley lands where it can be utilized. The major dependence, however, must be placed on a plant cover adequate to protect the soil against the occasional heavy rains. Because of climatic fluctuations this project will be more difficult in certain years than in others. Some years will have greater than average precipitation, some less. Wet year may follow wet year, or drought year may follow drought year in long series. Individual months will be exceptionally wet or dry, hot or cold. Occasional intense storms will deluge the land and, depending on the completeness of the plant cover at the time, may drain away with little erosive effect or may carve new channelways and enlarge old ones.

(Continued on p. 304)

FROM AN ARKANSAS DISTRICT REPORT

Excerpts from a semiannual report made by the supervisors of the Central Crowley Ridge Soil Conservation District, Arkansas, for the period ending June 30, 1940:

> In organizing the work for the district the supervisors set up six priority areas in the district and had these priority areas mapped solid. From the interest shown in the educational meetings conducted by the supervisors, assisted by the extension service, a concerted effort was made to secure applications from every land owner in these areas so planning and execution could be done with groups rather than with so many individuals. The wisdom of this policy was shown in the first area mapped. This area was small—only 27 farms—but of the 27 mapped, 25 became cooperators, one was already cooperating with the Jonesboro SCS Camp, which left only one out of 27 not signed to cooperative agreements. This one farm is owned by an absentee landlord. In other areas the solidarity of planning has been almost as successful. 201 district agreements have been signed, all in the six priority areas. The supervisors believe this policy reduces transportation, saves time of the planning technicians, makes possible more and better execution, but above all, it is felt that a more effective conservation program is possible through group action.

> Craighead County has been designated as one of the counties in Arkansas for county-wide planning by farmer committees assisted by representatives from various bureaus of the Department of Agriculture. This work has been proceeding for some time. The preliminary report has been prepared. It is worthy of note that the recommendations made by the county planning committee for the part of county embraced in the district coincides with the program and work plan of the district. It is felt that the work of the county planning committee will further the district program for conservation very materially.

> Arkansas State College, which is located within the district, is cooperating in a conservation program on the college farm. In addition to this, more emphasis is being placed upon agriculture and conservation in the curricula. Courses in conservation are being given and the college students taking these courses have made use of farms under treatment for laboratory and field studies. Members of the district personnel, upon request from the college authorities, have appeared as guest instructors before the classes studying conservation.

BOOK REVIEWS AND ABSTRACTS

by Phoebe O'Neall Faris

FOOD PRODUCTION IN WESTERN EUROPE, AN ECONOMIC SURVEY OF AGRICULTURE IN SIX COUNTRIES. By P. Lamartine Yates. New York, London, Toronto. 1940.

This is the "Report of an Inquiry Organized by Viscount Astor and B. Seebohm Rountree" in the years 1934–38. Mr. Yates, the author, was sent by them to Denmark, the Netherlands, Belgium, France, Switzerland, and Germany to study farming systems and the "marketing boards, quota systems and other measures of control which have grown up in recent years." There is a Foreword by Sir William Beveridge in which he emphasizes the reasons for giving a high place to the study of agriculture in schools of economics.

In view of the fact that war has intervened in the 2 years since the surveys and studies were made by Mr. Yates, it is doubtful that his leading question can be answered except theoretically for a long time. The question these Englishmen wanted answered is as follows: "How far has the agricultural development in these countries been beneficial to the public welfare as a whole? in particular, has it or has it not been advantageous to them to retain in farming a much larger proportion of their population than Britain?" The book here reviewed, describing the agricultural systems of the six countries, attempts to answer that question, war or no war, and to point without faltering to the end of hit-or-miss use of the land of Britain at least, with a remolded agriculture "to serve the public interest in a more consciously planned future."

The 600-page volume will be extremely interesting to American readers for several reasons: We in the United States have long studied the economics of agriculture; we are particularly concerned with increase or decrease in production in other countries, with future policies abroad; and we are in the midst of a vigorous planning program at this time.

Historically, the development of agricultural systems in Western Europe, with its peasant farmers, is so alien to the American way of thinking that it presents a most intricate puzzle-picture that must be put together piece by piece if we are to understand past and future trends. This book is exceptionally well organized, with countries treated separately but under almost identical chapter and sub-chapter headings. Under "Crops and Stock" are found descriptions of the natural features of each respective country, its land utilization policy, and its crop and livestock produce. "Farms and Farmers" is the title used above the detailed descriptions of each of the six countries with regard to farm size or holdings, the agriculture population, inheritance and "*parcellement*," land tenure, capital or land values, farmer income, housing, education, farmer organization and cooperation. A third chapter deals with the part of the state in the agricultural system of each country.

In view of what has come to pass within the past year in the six Western European countries, Mr. Yates' beautifully written book is intensely interesting, especially those parts dealing with government control. Reading through to the end, one is inclined to believe that in spite of tremendous and soul-destroying efficiency in some parts of Western Europe, little of true value has been accomplished in the way of agricultural planning for long-time security.

The war, no doubt, has answered the question that prompted the study undertaken by a small group of Englishmen 3 or 4 years ago. At any rate, it is fortunate for all of us that they decided to publish "Food Production In Western Europe" in spite of sudden calamity, because, as Sir William Beveridge states in the Foreword, "it is a contribution of common knowledge to the solution of a common problem."

AMERICAN FARMERS IN THE WORLD CRISIS. By Carl T. Schmidt. Oxford University Press, New York, 1941.

All agree that the present "agricultural dilemma," no matter what caused it, must be solved. In this, our country, the farmer group, of all groups, cannot be allowed to "sink." The farmer's job is production of food, feed, and textile materials; he must have income. The more he produces, whether he sells it or not, the bigger the dilemma! At this point one feels like crying "Help!" and passing on to less intricate and disturbing problems. Feels like it but doesn't, for the simple reason that one has the inborn conviction that in the farm family lies the future of the nation. The author of this book believes in the farm family, in the family farm, and in farmer ownership—the reader suspects that is why he wrote this book which might be called a frank, not to say pointed, appraisal of the objectives and attainments, and/or failures of agricultural adjustment over the past decade in the United States.

The book is much too long to be reviewed in detail; but a carefu reading plus notes, and a little "time out" for thinking, serves to clarify the picture as the author sees it—of the causes of present-day rural distress, of the original objectives of the adjustment program, and of just what thus far has happened as a result of that program. Questions the author attempts to answer by logical weighing and measuring are these: How much have the adjustment programs helped agricultural income? How have gains been distributed—among landlords, corporation growers, tenants, laborers, family farms? At what cost to farmers have gains been made—who paid for them, farmers or non-farm people? What has been the financial cost to the Government in subsidies and administration? What do the programs mean for the future?

A very long analysis-discussion of the farm-payment plan brings out some little-known facts and some new ideas as to real values. Under a heading, "Distribution of Benefits," the payment benefit is discussed as to effects on large commercial farming, the family farm, tenants and laborers. The hired man is called the "forgotten man" of American agriculture with almost no chance to climb, even one rung, toward the top of the agricultural "ladder." According to Professor Schmidt, he has had the worst of it. Striking also is the contrast of benefits, as shown by this book, to the farm family upon which the nation is largely dependent for preservation of democracy and benefits to the farming corporation. The author feels that share- tenants, croppers, laborers have benefited little; many have lost employment and homes, such as they were, through payments to larger farmers and landowners who were thus enabled to buy means for mechanized farming. One point, significantly brought out by the author, is that of present means and laws in certain areas, permitting the landlord to grab the tenant's share of benefit payments.

Professor Schmidt is not chary with praise of long-range farm credit; of farm security methods as the cure for the very poor and family farm ills; of actual soil conservation work on the land; of the planning work of the Department of Agriculture with its economic research and cooperation with farmers and farm communities in the effort to get away from interest-group planning to broad social planning; of government administration of agriculture in the past decade.

The first part of the book is given over to what might be called a "comedy of agricultural errors" over the past century in the United States. It includes discussions of causes—causes of what is called the "present agricultural dilemma:" mortgaged farms; tenancy and lease terms; wide diversity of farm conditions; market systems and the world's and the nation's economic changes and depressions. Summed up, the "dilemma" is, according to Professor Schmidt, the result of (1) farms being tuned in the past to supply both domestic and foreign demand; (2) decline of foreign demands; (3) mechanization, too suddenly, on the farm; (4) farmers being confronted by big business in selling their produce as well as by export tariff. The author sees United States agriculture, in world crisis, war and war's aftermath, faced with collapse of foreign markets, with the facts that other countires with cheap land have underbid us and that world international trade has become not merely "cutthroat" but retaliatory. Manufactured articles have taken the place of farm produce as exports—thus Professor Schmidt sums up the crisis, and "All in all, the United States can no longer regard itself as the granary and the cattle ranch of the world, and its exports of food and fiber seem destined, except possibly in time of war, to continue to decline in importance." This statement may be contested, vigorously, figures or no figures, by many; yet it is nonetheless thought provoking.

Here and there, some most significant statements turn up between the covers of this volume: ". . . demands for foreign vegetable oils, fibers, and fruits have increased." . . . If urban employment does not expand, the mechanization and abundance of agriculture is likely to be retarded and this may bring about a more self-sufficient farming. ". . . The most important way in which farmers try to help themselves is by political action." . . . The effort to save soils is a major exception to failures thus far to build up a stable agriculture . . .

It might be said that the author has familiarized himself with the functions of government agencies in agricultural adjustment only to a certain extent—he has a habit of using triplet initials when referring to the whole great program for a stabilized agriculture. In the final analysis, however, he gives us some problems to be worked out in the near future. Here they are, summarized very briefly: (1) Adjust the benefits, both Federal and those from the land, to human needs—give the disadvantaged rural people a chance, the smaller, poorer farmers, the tenants, the farm wage workers—so that in the broader sense the benefits may be distributed according "to the needs of the whole people in the future." (2) Stimulate demands, foreign and domestic, without trying to reduce production. (3) Encourage the farm-family way of living.

Thus at the very end of the book, the farm family comes into its own again, as at the beginning. Professor Schmidt, who is on the staff of the Department of Economics of Columbia University, New York City, displays in this new book a most exceptional appreciation of the significance of the present trend in American agriculture.

CLIMATE OF SOUTHWEST

(Continued from p. 302)

In spite of the large fluctuations that are characteristic of the climate of the Southwest and that at present cannot be forecast, intelligent action to reduce the irritation, increase the protection to the surface, and reduce surface run-off and loss of water will go far toward the control of accelerated erosion and the rehabilitation of the region.

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A GEOLOGIST PRACTICES SOIL CONSERVATION

By H. ANDREW IRELAND [1]

DURING a recent trip to Oklahoma, I had occasion to spend a few days traveling with a fellow geologist who told me the story of his "back to the farm" movement during the hard times of the early 1930's.

Malcolm Oakes is a great big husky fellow, honest, kind, and a friend worth having. He was raised in Oklahoma, and to me, has all of the qualities of the pioneers who opened up the West. He has a head full of stories and knows Oklahoma intimately. I was astonished by his familiarity and personal knowledge of places, people, and geologic details. Going along he would remark, "Now, over there in that hollow," or "Just behind that tree beyond yonder barn," or "On that hill across the river," and then proceed to tell something interesting. He was good with fish stories, too.

Malcolm is a competent geologist, and until the depression he had a good position with an oil company. But, like many other good men, he was laid off and lived on his savings for some time.

One night an examination of his financial condition revealed enough funds to last only a few months. Between him and his wife it was decided that something had to be done before the funds were exhausted, while there was still a bit of operating capital.

Said his wife, "You were raised on a farm but I wasn't. However, I am willing to make a try at farming if you think we could manage it."

"At least," said Malcolm, "we could raise enough to live on and it would provide a means of getting Dad away from the city. You know Dad is over 80 and the country might do him good. The girls could go to school by bus."

A farm of 160 acres in northern Oklahoma County, a team of horses, some second-hand machinery—these were purchased for a small sum. Now, if you know that part of Oklahoma, you know that the country east of Edmond is about the reddest, sandiest, hilliest, and most eroded and gullied land in Oklahoma. Dense blackjack oak covers the upland and cocklebures, sand burs, and willows grow along the streams. What Malcolm Oakes and his wife did to that farm was the wonder of the local residents and others. The success they achieved is worth knowing, and here lies the point of this story.

The early history of Malcolm Oakes is important in the rejuvenation of this worn-out farm. When Malcolm was a boy he lived on a sand hill farm 3 miles southeast of Ashland, Okla., in southwestern Pittsburg County. His father, John Thomas Oakes, was a progressive man and one of those rare early pioneers in soil conservation like the father of Angus McDonald. (See "The Soil Builder," SOIL CONSERVATION, September 1936; also "My Father Was a Soil Builder," Harper's Magazine, December 1940). The agricultural bible of the Oakes was an English book owned by Malcolm's grandfather called "Blakely's Industrial Encyclopedia."

In 1899 John Thomas Oakes decided to terrace his farm, a small one of 17 acres. Malcolm was given the task of making a striding level from the descriptions in Blakely's Encyclopedia. The terraces were run with a slope of 2 inches per hundred feet with a home-made hand level consisting of planks and a carpenter's level. Water was conserved, soil was conserved, and the corn production increased. The first year 20 bushels of corn per acre were harvested but within 4 years the yield had risen to 60 bushels. Cowpeas and peanuts were used between the corn rows and for winter cover. Malcolm said they had 51 acres of crops because they grew 17 acres of corn, 17 acres of cowpeas, and 17 acres of peanuts. An additional asset to good production was the location of the farm on the dip slope of the Savanna sandstone which contains phosphate nodules. The phosphate had been leached and carried away, until the terraces were built to retain the water with its phosphate and other plant nutrients.

As he prospered, John Thomas Oakes acquired more land and constructed dams for ponds and water conservation. His dams rarely washed out. His success was due to limiting the dam so that the drainage basin was not more than five times the area of the pond. The water level was traced with the previously mentioned modified carpenter's level. The dams were always located on a bit

[1] Associate conservationist in geomorphology, climatic and physiographic division, Soil Conservation Service, Washington, D. C.

of open prairie because the natural grassland indicated shale bedrock, and shale held water. Such reasoning was typical of this pioneer conservationist.

Later the farm rights were sold to a man from Iowa. All land in this area belonged to the Choctaw Nation but farming rights were bought and sold until the time when the land was divided and each member of the Choctaw tribe was given full title.

The Iowa farmer was proud of his agricultural ability, his knowledge of farming and the fine machinery he brought with him, yet from the date he took over this farm it began to deteriorate. Wonderful, straight, and accurately placed double check rows of corn were planted and the terraces were over-run by tractor, plow, and cultivator. Also the rains came and washed the soil down the check rows and removed the phosphatic nodules. Twenty years later the farm was ruined and today it resembles a rock pile more than anything else. Bedrock outcrops nearly everywhere, and only a few bales of cotton from poor scraggly stalks can be grown on what was once 17 acres of the finest land in Pittsburg County.

Malcolm Oakes went to the University of Oklahoma and became a geologist, interested in rock and oil rather than soil and farming. But in lean days he recalled his father's training and turned again to the soil. To his early farm training he had added a knowledge of geology, chemistry, and the habit of scientific thinking. He accepted the challenge of the old worn-out farm.

The red, sandy, gullied blackjack farm which he bought cheap was worth less than he paid for it, just to look at it. What would it be worth if properly farmed? The house was fairly good, possibly worth the price of the whole farm, so he considered the land as a gift.

The big gullies on the slopes were too deep to fill, but the small ones he checked by terraces made with a plow and the team of light horses. Each time around with the plow made each terrace drain a foot wider until it was 6 feet wide, and the terrace became higher and broader. A neighbor, seeing the terraces, could not believe that they had been made with a plow and a light team. Brush in the gullies and the retention of water by the terraces reduced the gully erosion. A crop of cowpeas reduced the sheet erosion. Later, some of the deeper gullies were filled; he used a slip scraper for this. Most farmers scooped off knobs and elevations to fill their gullies, but Malcolm Oakes scooped out the bottom of his terrace drain. He used subsoil for fill instead of the topsoil. And he scooped out holes or pockets in the terrace drains so that any washed topsoil was retained, not allowed to go down the gully.

Twenty acres of formerly fertile land along the creek were covered with 4 to 6 feet of infertile sand from gullies on farms upstream. A thick growth of young willows covered the whole bottom. A dozen rounds with the plow loosened the sand between the larger willows along the former stream channel, and the first rain washed out the loosened sand. Neighbors were puzzled at so much work for apparently nothing. But Oakes repeated the process of plowing the channel after each rain and in a few months he had a channel that hid the horses.

After the first plowing of the channel he mowed the young willow thickets, and then removed them several times until a fine stand of volunteer sweetclover developed. This, when young, made good pasture for the cows. The cows did not like the sweetclover when it was tall, tough, and mostly stems, but continued cropping by the cattle kept it from growing to an unpalatable stage.

When high water came up in the spring the overflow deposited good topsoil over the bottomland, and the coarse sand remained in the deep channel where the current was strongest.

Ingenuity about the house and farmstead gave greater comfort and relieved the financial situation. The cattle needed only one water tank, so the extra one was placed on a platform made out of blackjack poles cut from the woods. A cover was made from charred but strong lumber from a burnt barn. At first the windmill pumped water to the tank and a garden hose conveyed it to the house where a wood stopper served as a faucet. Later, discarded pipe was substituted and the wash basin, bathtub, and sink were drained to a flower bed and lilac bush. Plumbing thus entered the life of this geologist turned farmer.

Occasional geologic jobs for a few days or weeks augmented the family finances, and other improvements were started. A gas pump furnished the water supply for the house and stock and to irrigate

(Continued on p. 312)